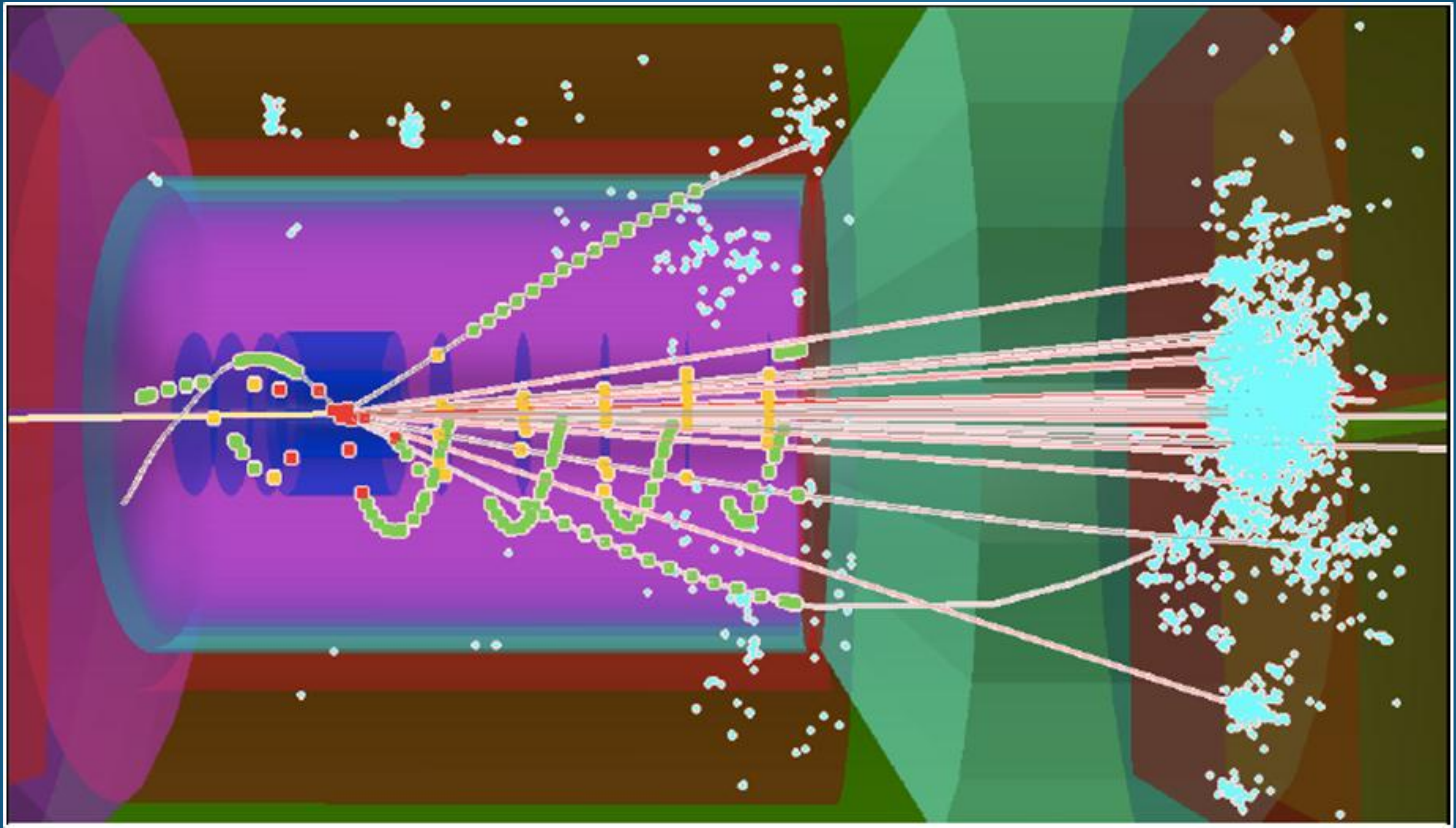
RD6 – Tracking Consortium



T.K. Hemmick

Outline

- Detector Research Goals:
  - Central Arm: TPC+HBD combined detector.
  - Forward Endcaps:
    - Planar GEM detectors
      - Large area
      - Possibly providing a vector-stub
    - CsI photocathode RICH.
      - CsI cathode technology well known.
      - Large area mirror development is current focus of R&D.
- Broader Program Impact:
  - Participated in organizing simulation workshop.
  - Holding joint meetings with Calorimeter Group.

Collaboration Status

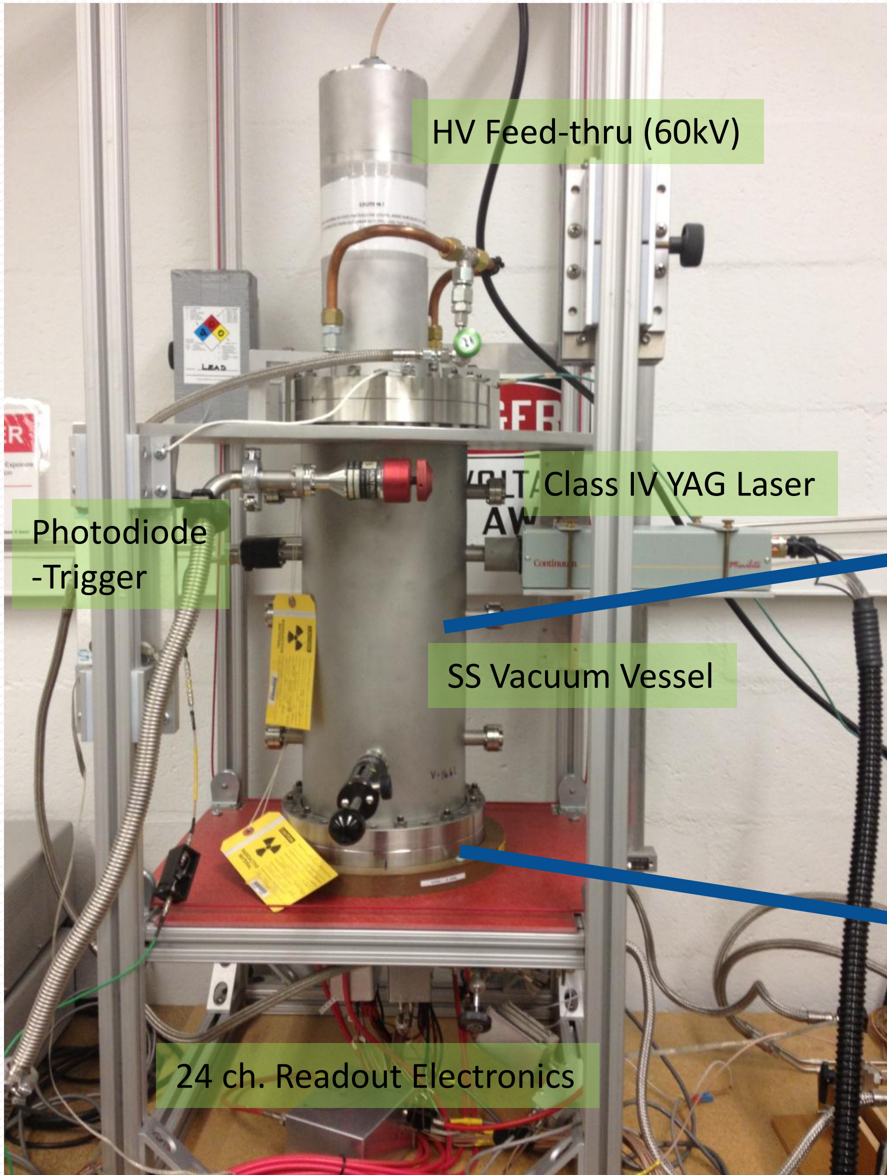
- Funding cycle from May 2012 “straddled” fiscal year.
- Strategy for first funding portion:
  - Fully fund hardware postdoc.
  - Minimally fund ongoing hardware efforts.
- Search Results Excellent!:
  - 19 applications.
  - 5 selected for interview.
  - Interviews next week..
- Further development:
  - Nils Feege hired to spin group @ SBU.
  - Recently arrived and will dedicate major effort to EIC.

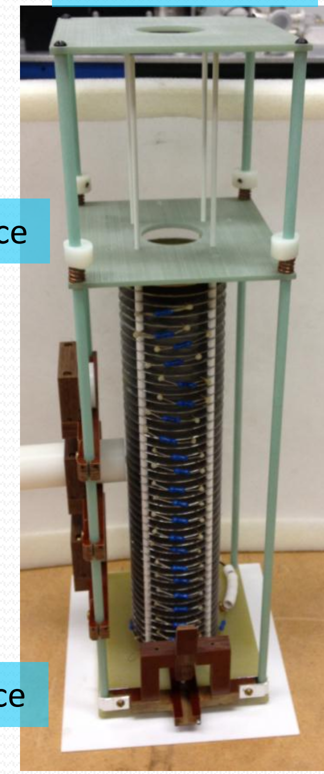
Central Arm: Fast TPC with RICH

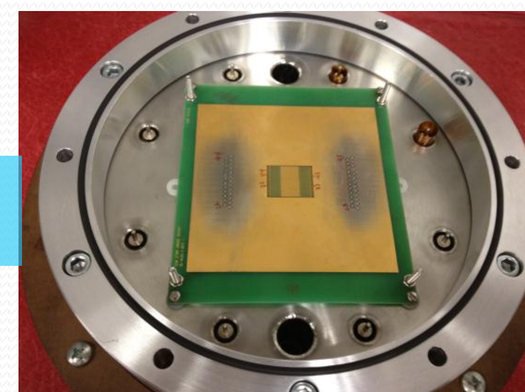
- Studies have begun to investigate TPC/RICH gas mixtures
  - TPC test setup now up and running at BNL
    - required resurrecting laser, HV supply, safety approvals, etc.
  - Started measuring charge attachment, gas transmission, etc
- Started designing first small prototype detector using 10x10 cm^2 GEMs
  - Preliminary field cage design
    - will need more sophisticated electrostatic program in the future
  - Started mechanical design
  - Acquired readout electronics from STAR Forward TPC
    - looking at other readout electronics from PANDA and ILC groups
- Hope to have a prototype detector w/readout system ready for a beam test in the second half of 2013

- Don't need as much light as PHENIX HBD (eID, not Dalitz Rejection)
  - More flexibility in gas mixtures.
- **Major issue:** Electric field compatibility between TPC and HBD sections

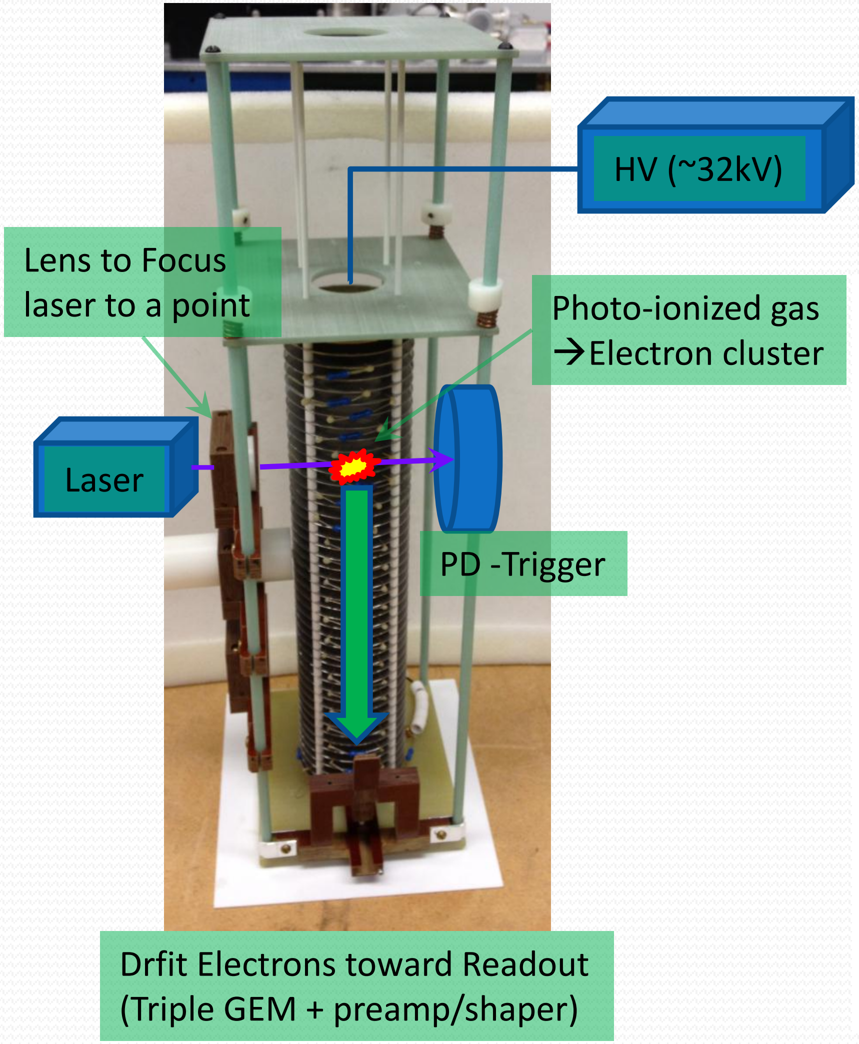
TPC Test Set Up



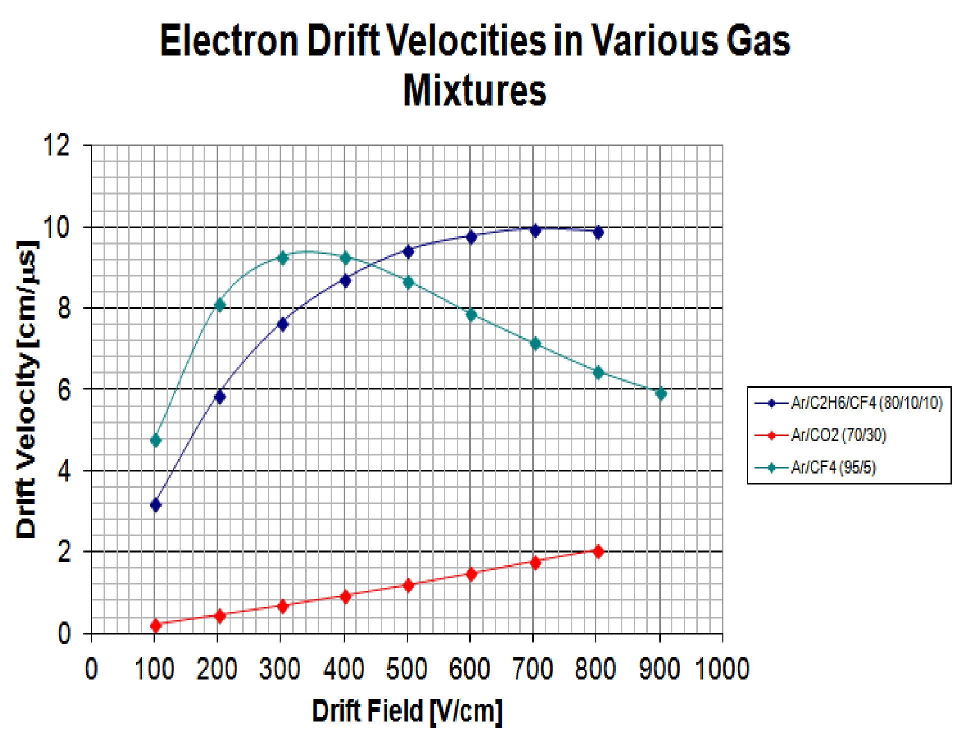




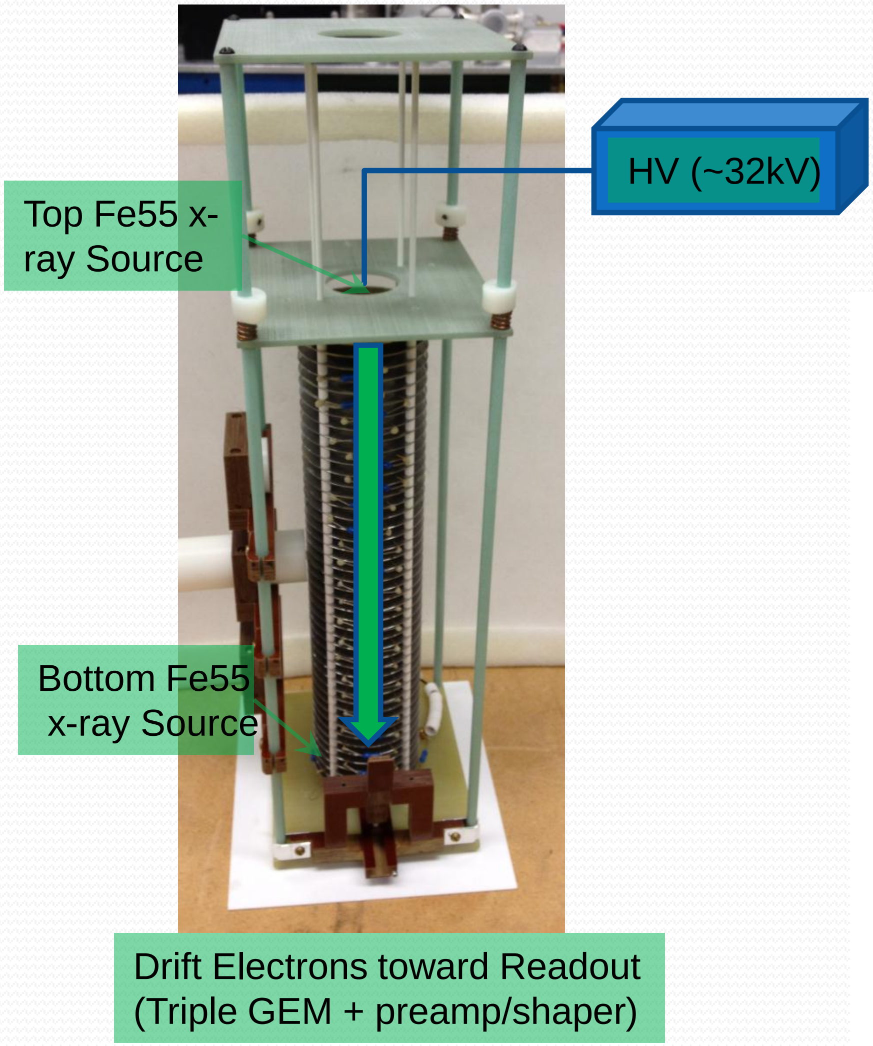
Drift Velocity Measurements



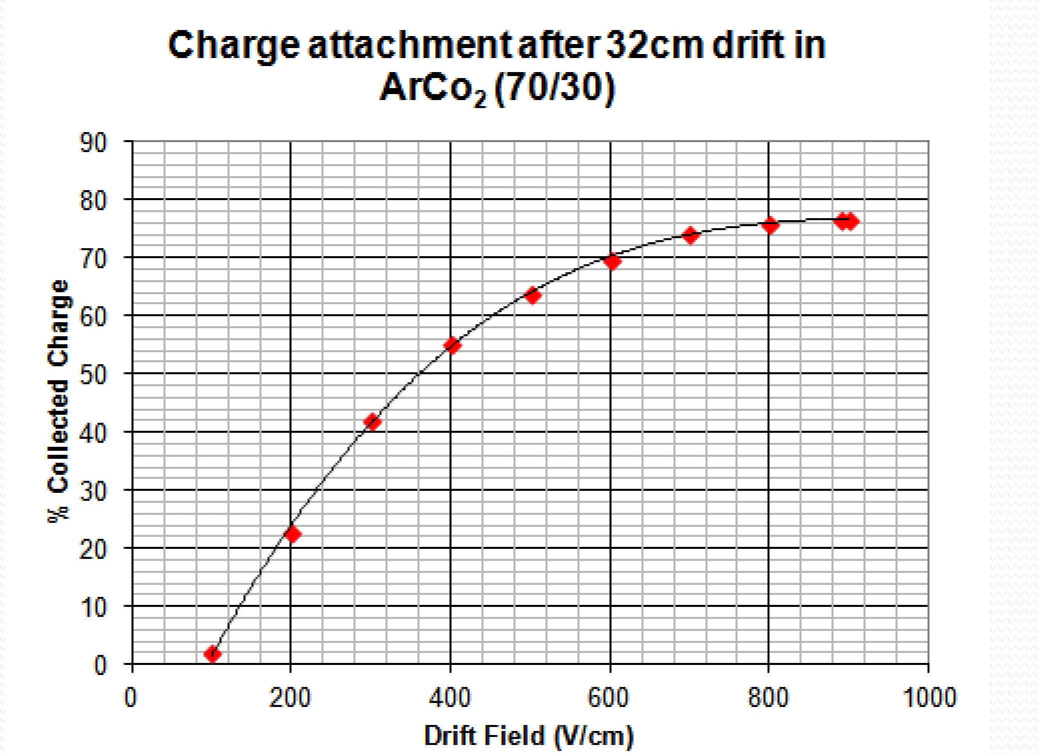
- The PD provides a trigger at the time the laser produces the cluster of electrons.
- The drift time is then measured as the arrival time of the charge cluster at the readout.



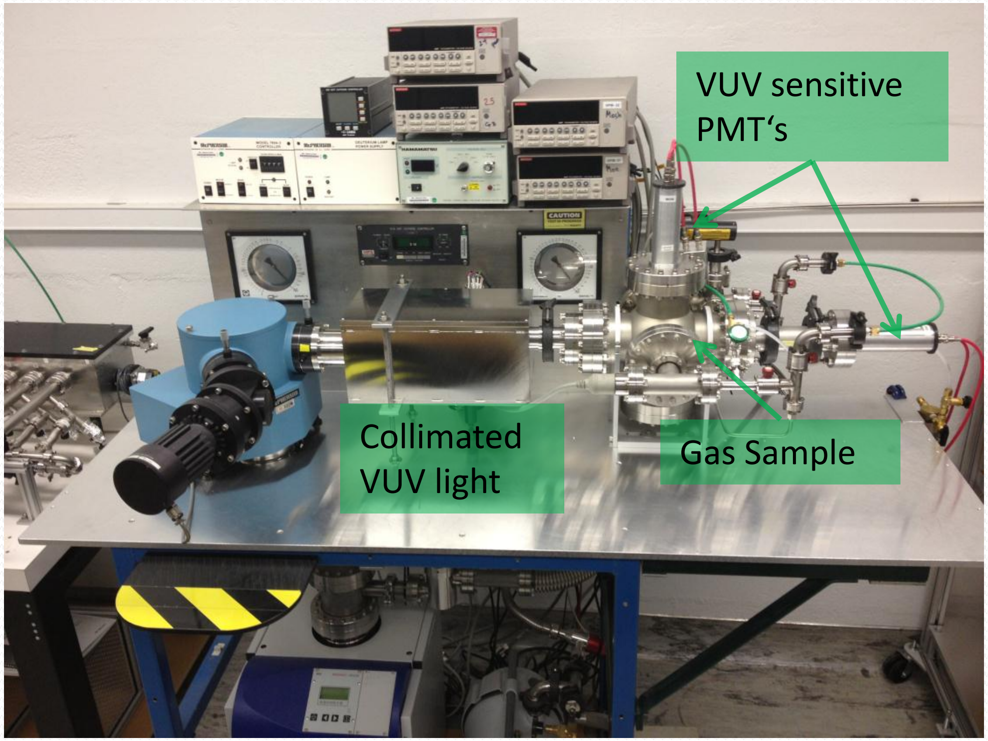
Charge Attachment Measurement



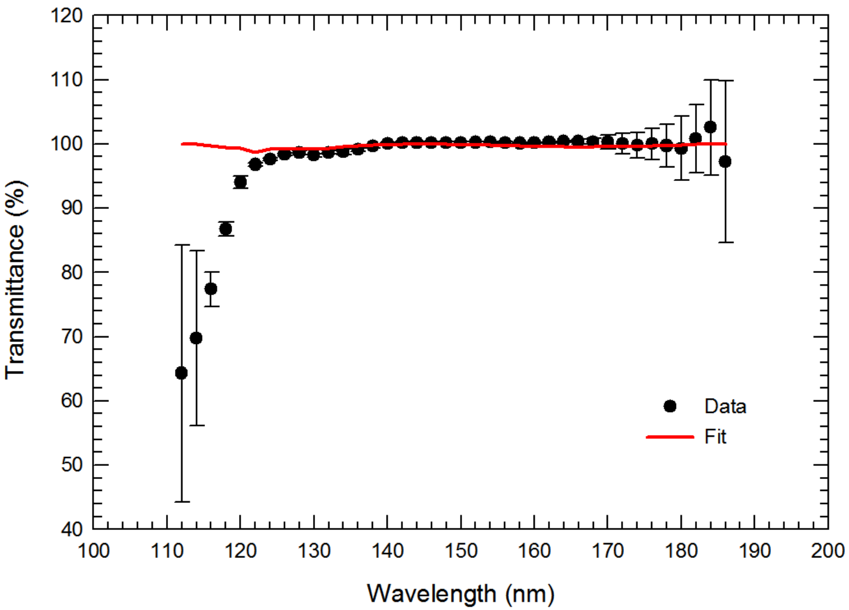
- As electron clusters produced by the top Fe55 source drift toward the readout, they lose charge due to charge loss mechanisms within the gas.
- The amount of lost charge may be measured by taking the ratio of the total charge measured at the readout from the top source (~32cm drift) and the total charge measured from the bottom source (~0cm drift).



Gas Transmittance Measurements

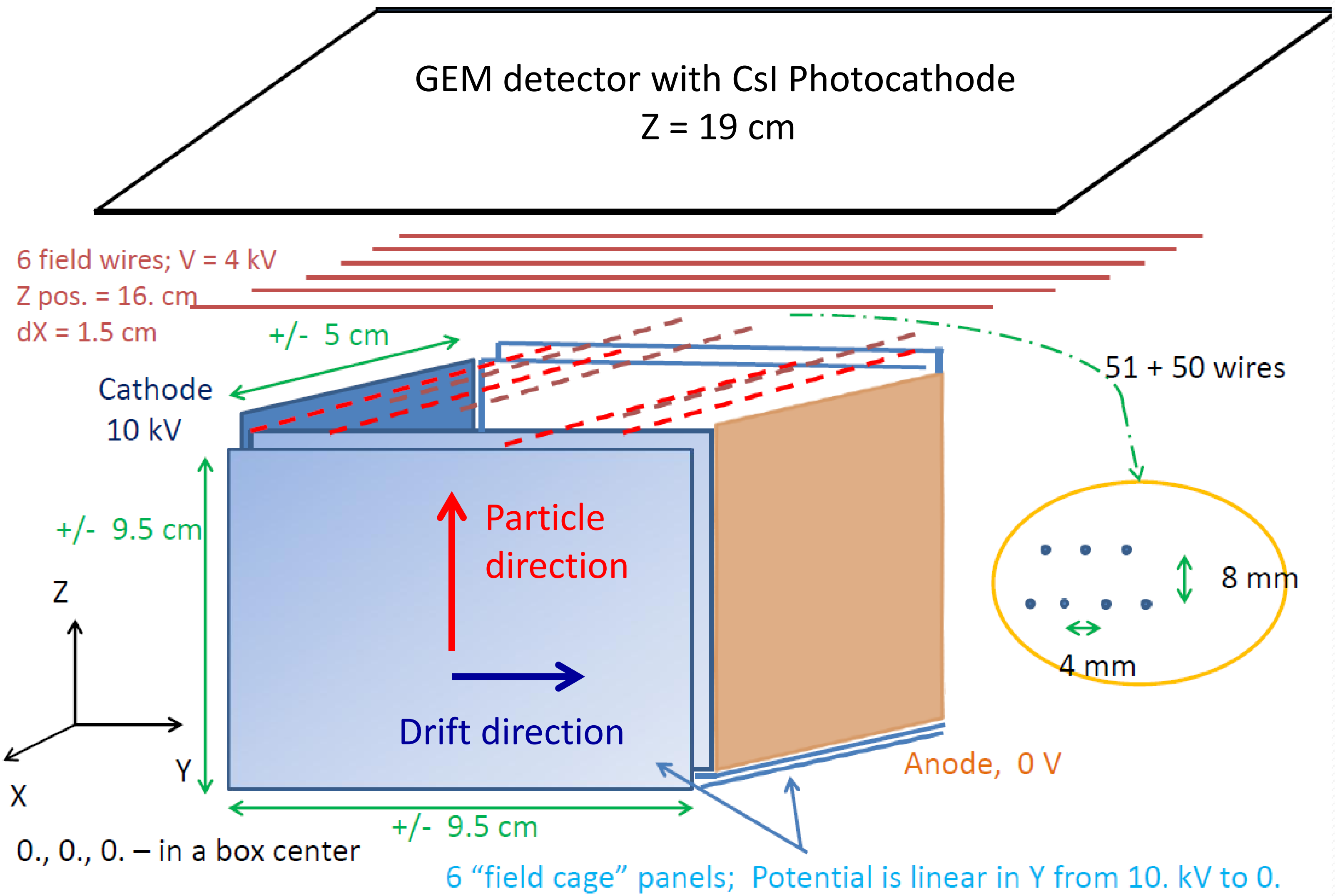


Transmittance of pure CF4

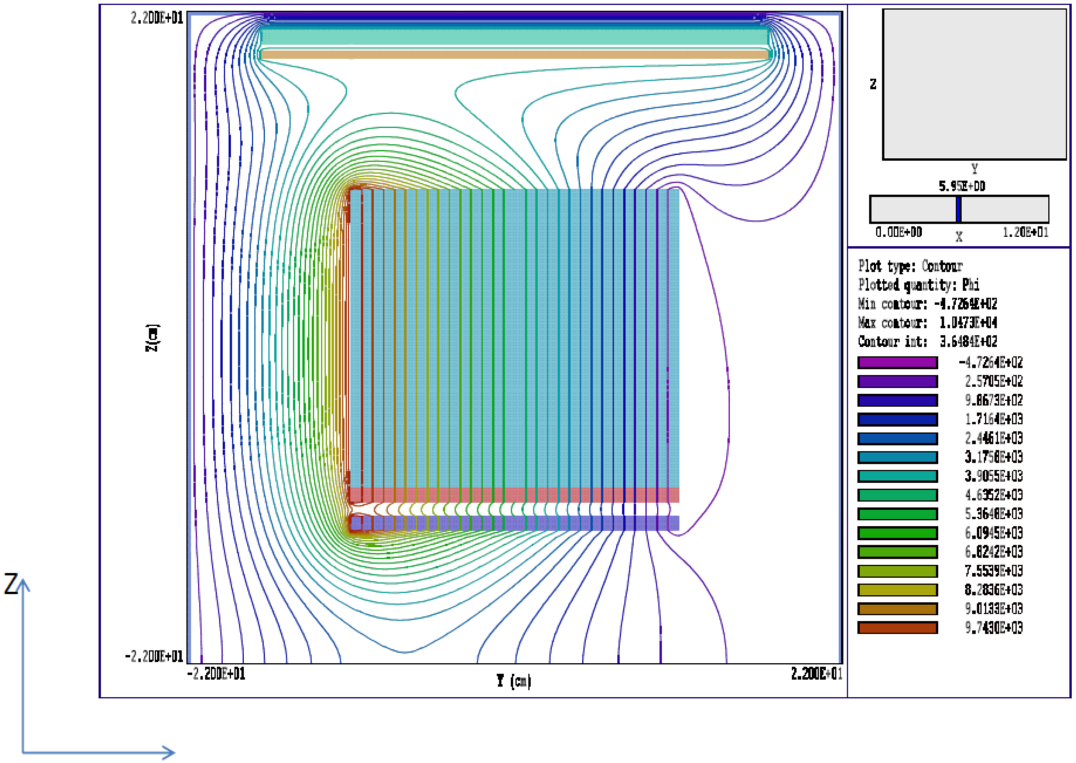


We have the ability to measure the transmittance of various gases within the lab, which is necessary for studying drift gases that must also be transparent to Cherenkov photons.

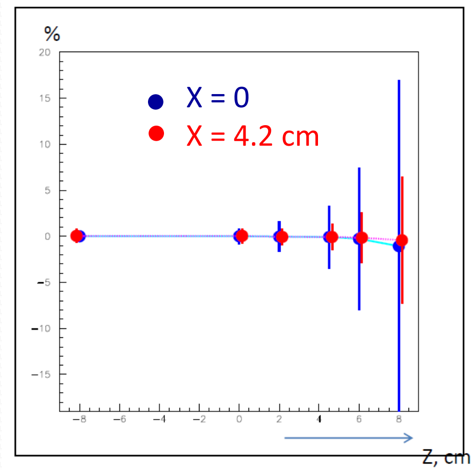
Prototype TPC/RICH Detector Design



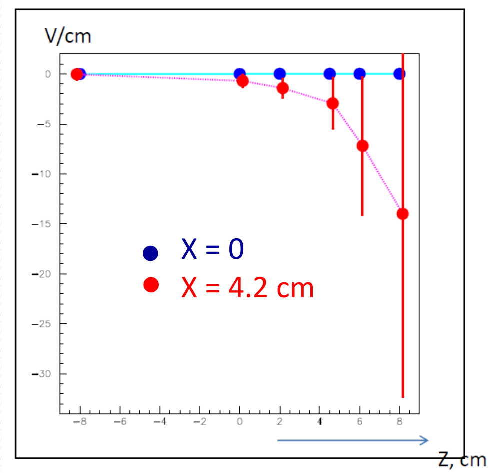
Prototype TPC/RICH Field Cage Simulation



$(E_y/\langle E_y\rangle - 1)$ (%)



$(E_X$ (V/cm)



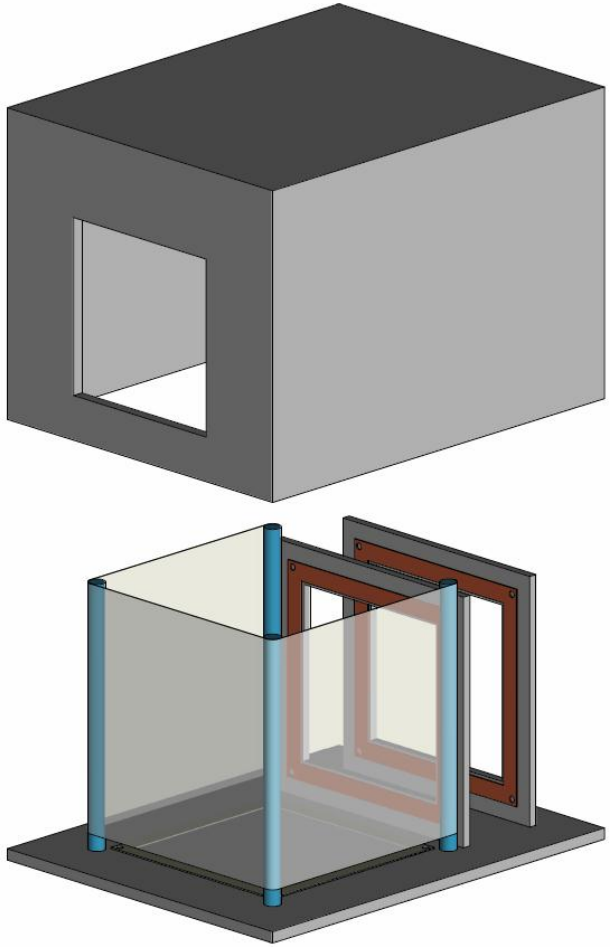
Electrostatic simulations done with Amaze 2.0 + HiPhi 2.5

- Free, but very limited in terms of capabilities, resolution, etc
- Need to use more sophisticated program (e.g., 3D Maxwell, Garfield, etc) in the future

CONCLUSION: 9 cm gap should resolve HBD vs TPC electrostatic issues

Conceptual Prototype

- Particles impinge from left.
- “Transparent” wire field cage.
- Vertical drift for TPC section.
- Photo-sensitive region at particle exit.

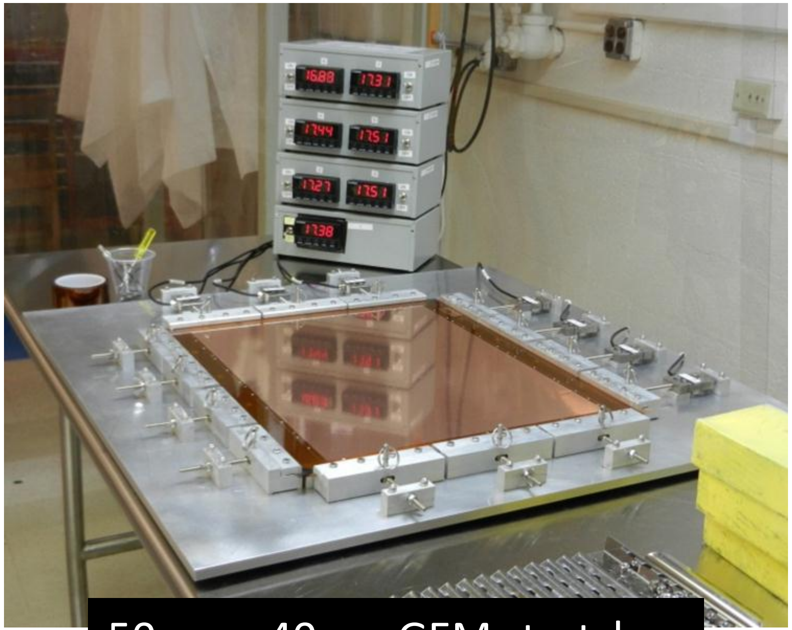


Forward Endcap:

- Principle Tracking Issues:
  - Size of GEM frames and mechanical details.
    - V-shaped "octagonal" sector.
    - Development of S4 tensioning scheme.
  - Gas volume.
    - Development of vectoring using extended drift gap.
  - Readout Options.
    - Diagonal strips.
    - Zig-zag
    - 3-coordinate.
- Principle low-n cherenkov issues
  - In-house mirror development

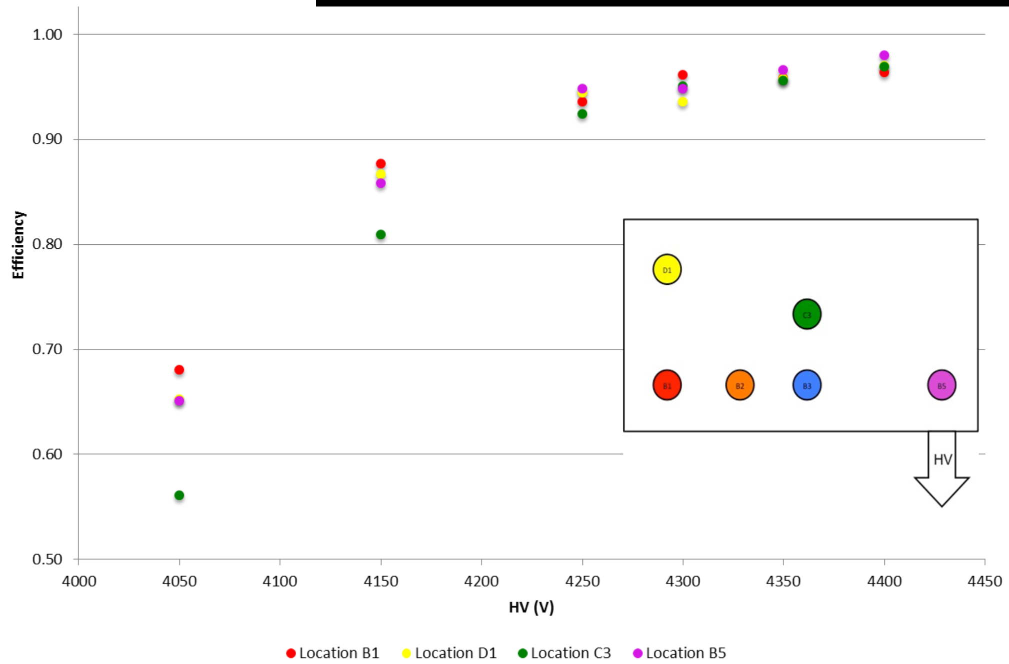
University of Virginia EIC detector R&D Status

- Successfully constructed and tested a midsize (50 cm x 40 cm) prototype GEM that contains the features planed for the UVa EIC GEM module.
    - Stretching technique worked well; optimum tension found.
    - module with narrow edges holds tension well, no foil or chamber deformation under tension.
    - GEM chamber works well, under testing now.
    - One problem discovered: metal dust from stretcher screws contaminating the chamber. The solution: fabricate stretcher part out of hard plastic.
- The design of the UVa EIC GEM module is complete. The GEM foil orders have been placed.
- The design of the 2D readout board is underway.



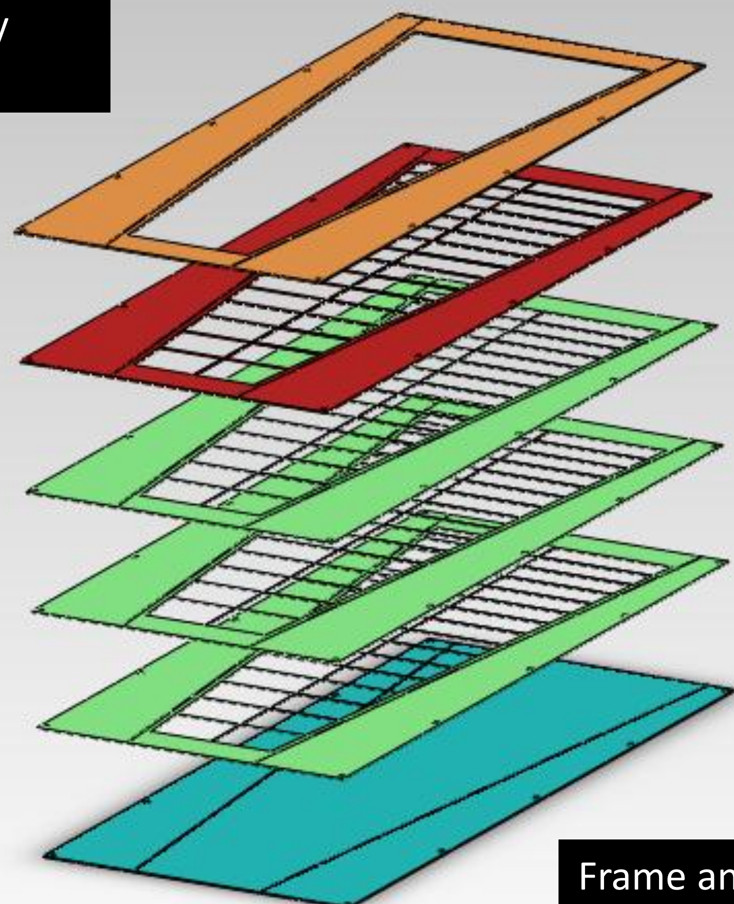
50 cm x 40 cm GEM stretcher

40 x 50 GEM module efficiency as a function of position and high voltage



UVa EIC GEM module frame design

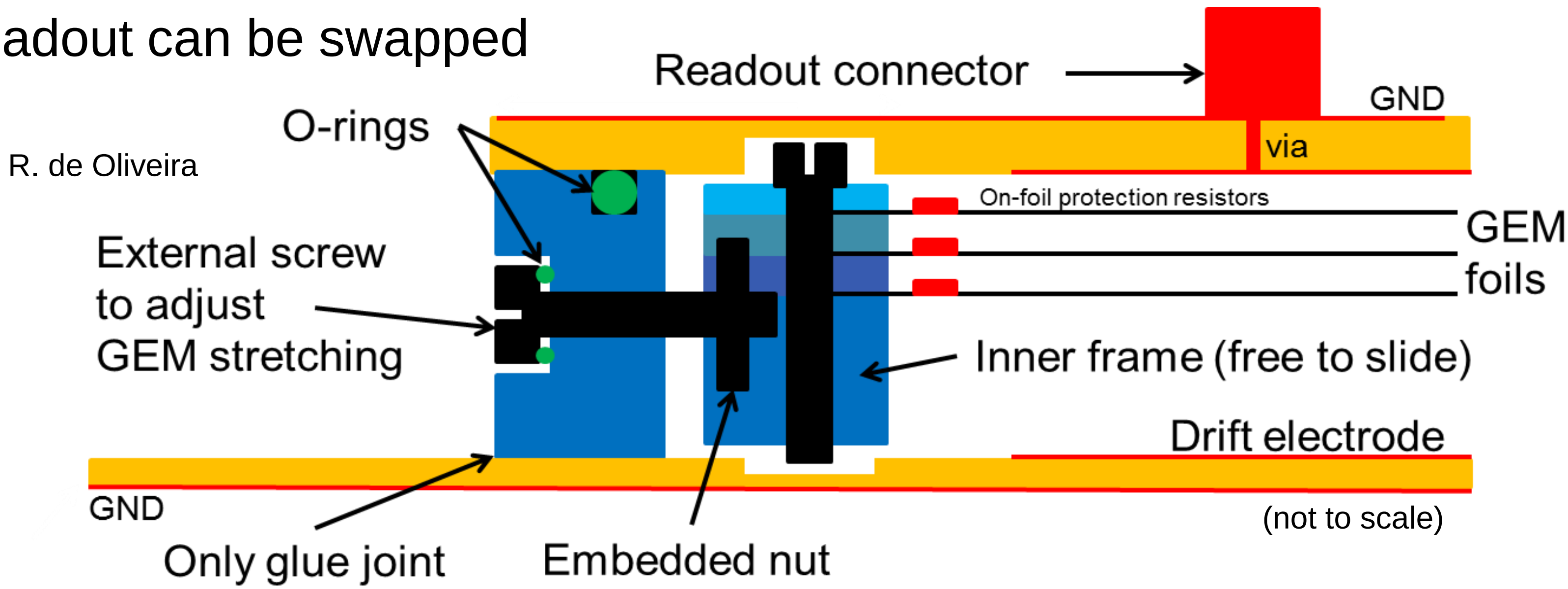
The “wings” on each plane are for support during assembly. These will be removed once the chamber is fully assembled, leaving 8 mm sides.



Frame and foil design is complete; order placed with CERN GEM workshop.

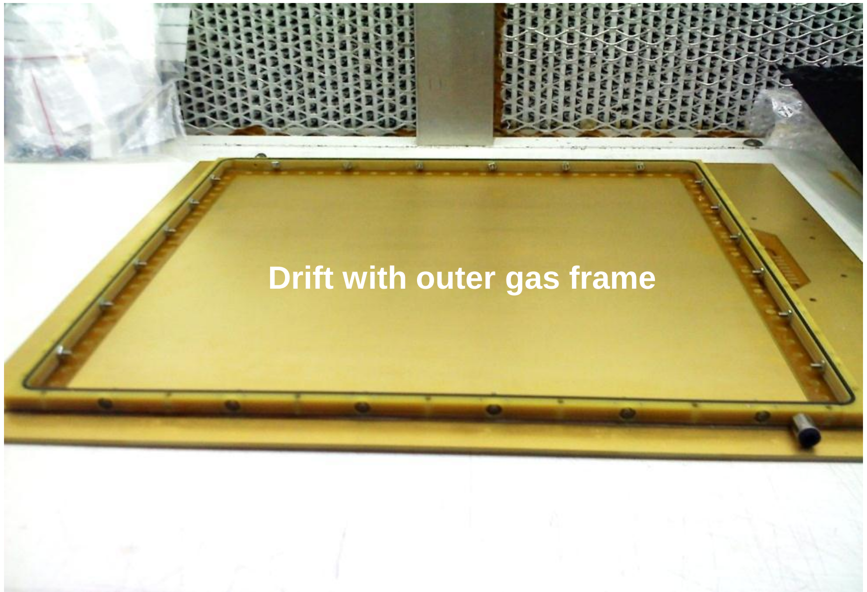
EIC 30cm × 30cm S4 GEM

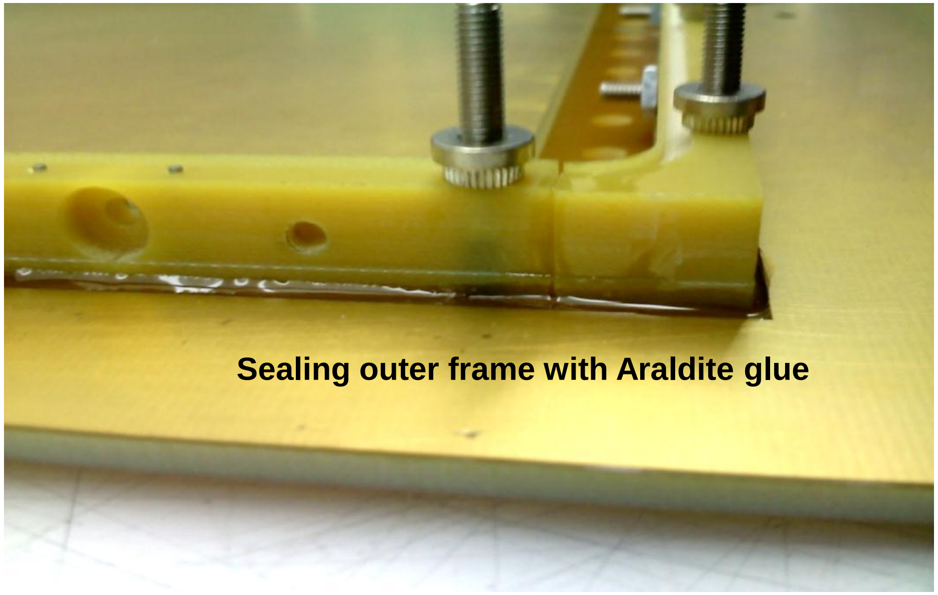
- Simplified "S4 (**s**elf-**s**tretched, **s**ans **s**pacer)" construction
  - self-stretched: No more gluing of GEM foils onto spacer frames
  - sans spacer: No more spacers inside active volume
  - Readout can be swapped

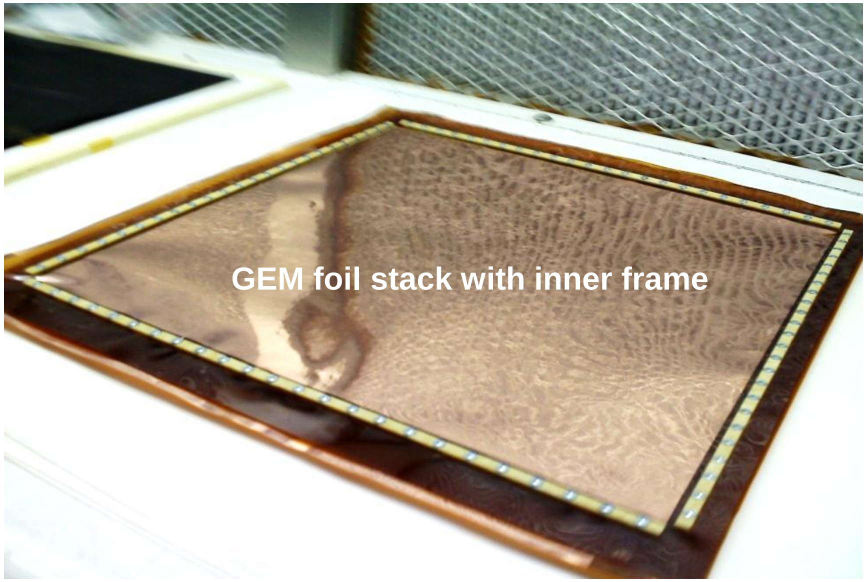


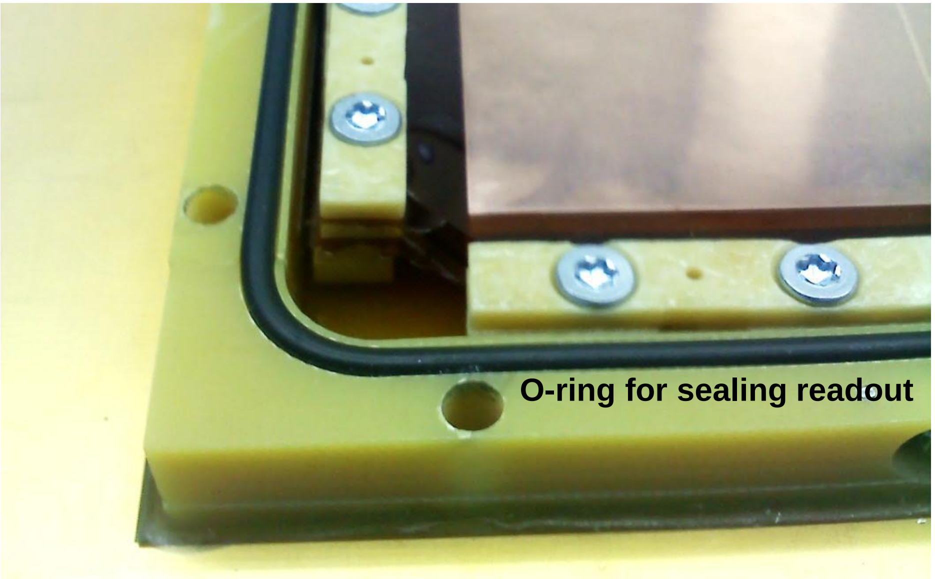
- The parts for a 30cm × 30cm Triple-GEM were procured from CERN (Rui de Oliveira) using funds from this project
- Detector was built in a cleanroom flow hood by a student, who systematically recorded issues encountered with construction

30cm × 30cm S4 GEM





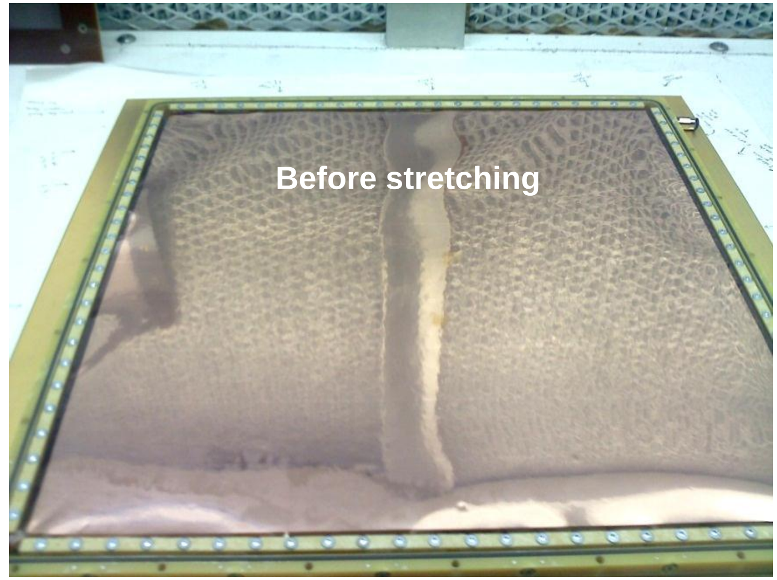


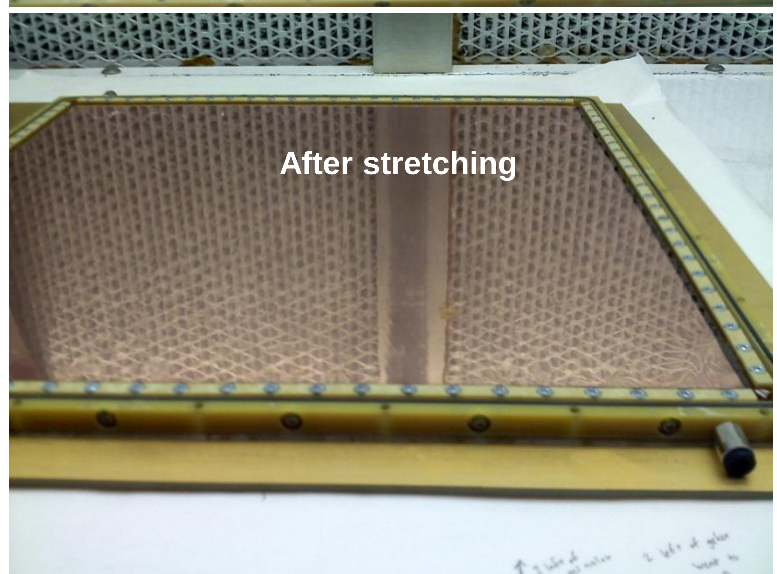


J. Twigger

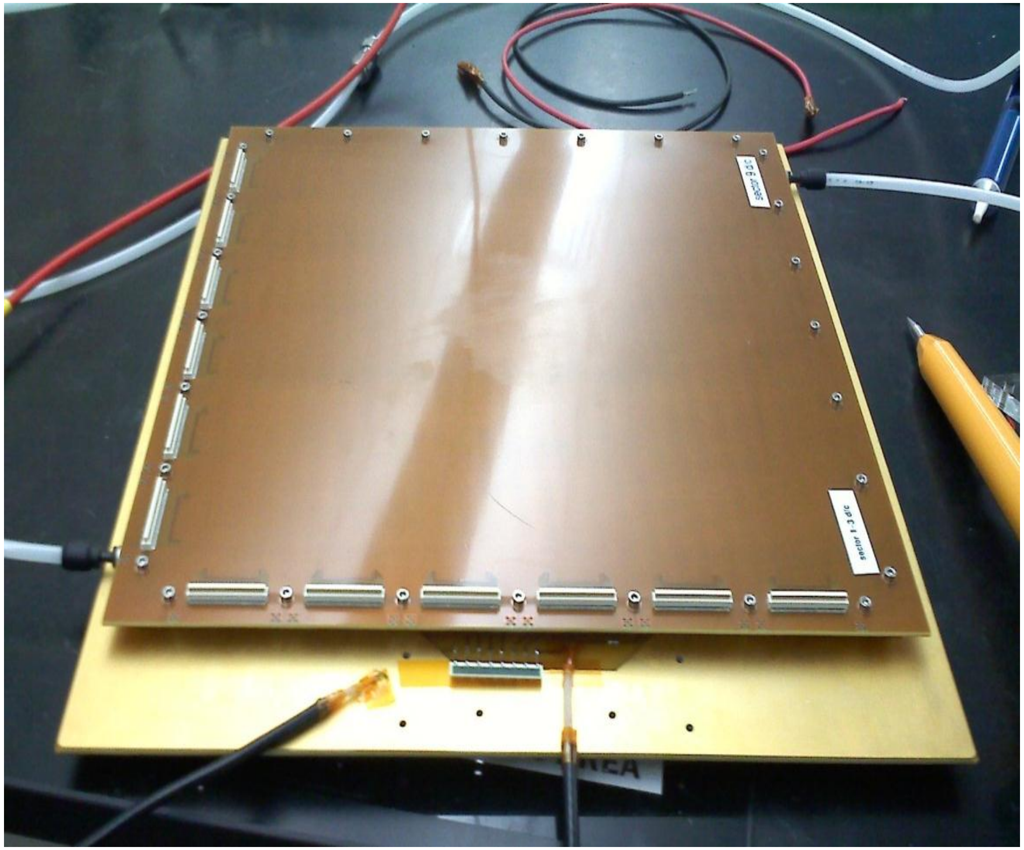
GEM foil stretching

- Foil stretching is fairly straightforward and can be monitored visually
- After sufficient initial tightening we follow Rui's instructions of placing the readout board on top and continuing to stretch
- We monitor for sparks when voltage is applied between adjacent foils in air and adjust tension accordingly until no more sparks occur

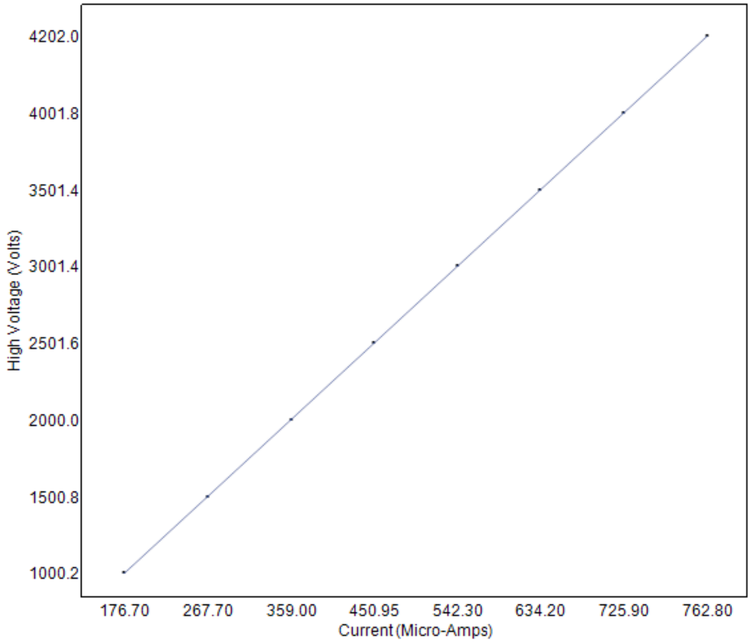




EIC Completed S4 Triple-GEM

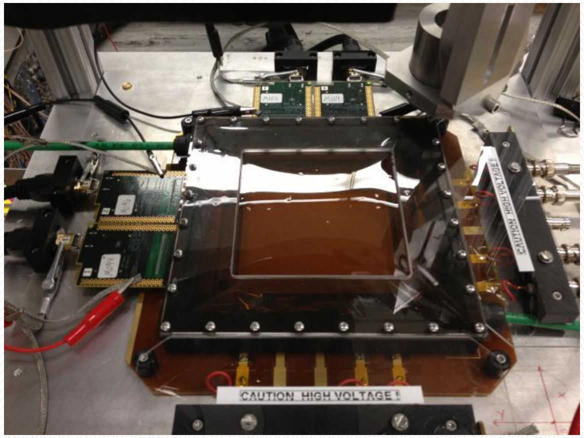


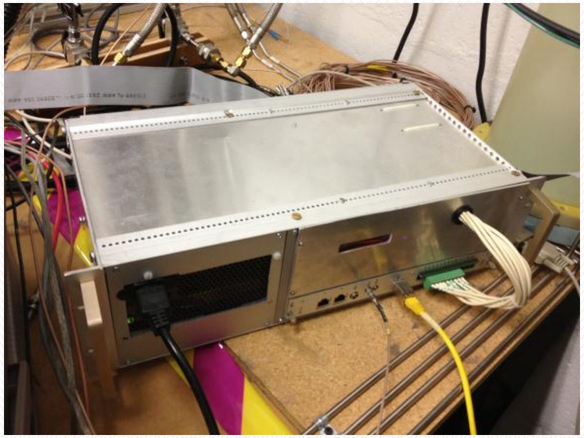
First HV test of completed GEM detector in 100% CO_2

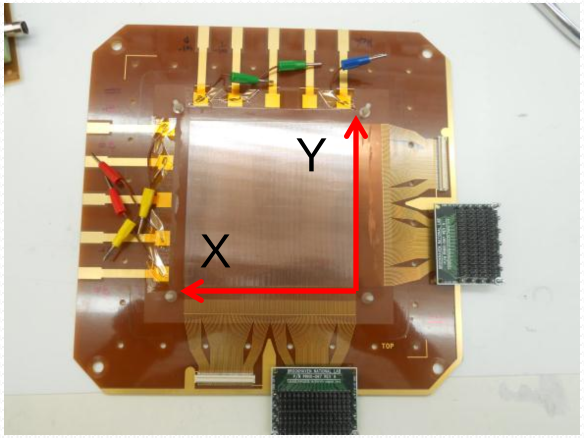


Current in HV divider

Mini-Drift GEM Det. + SRS Readout



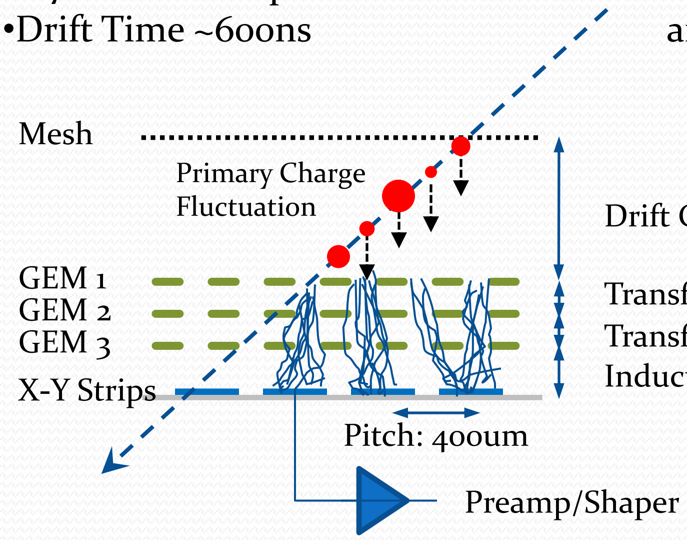


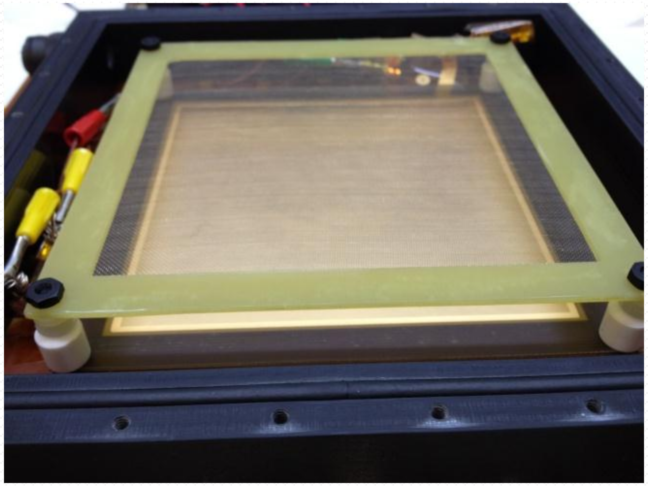


Std. 10x10cm CERN 3-GEM Det.
- ArCO2 (70/30)
- Gain ~ 6500
- ~17mm Drift Gap
- Drift Time ~600ns

SRS /512 channels APV 25
- 30 x 25ns Time Samples
- Martin Purschke's newly developed RCDAQ affords high flexibility

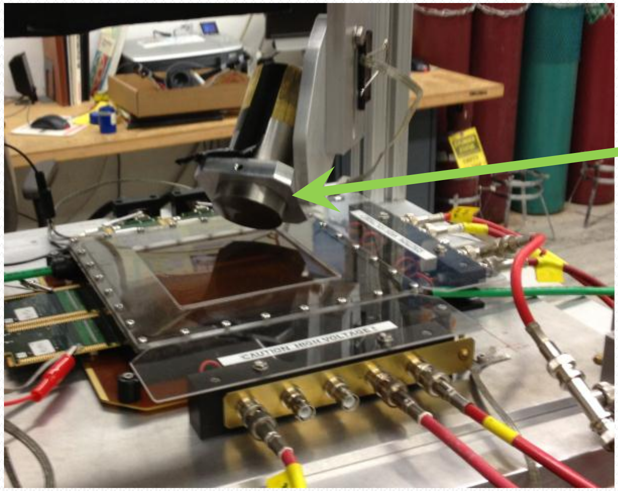
COMPASS style Readout:
- 256 x 256 X-Y Strips
- ~10cm x 400um pitch

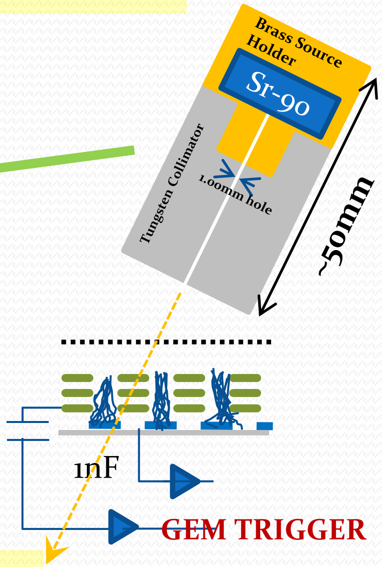




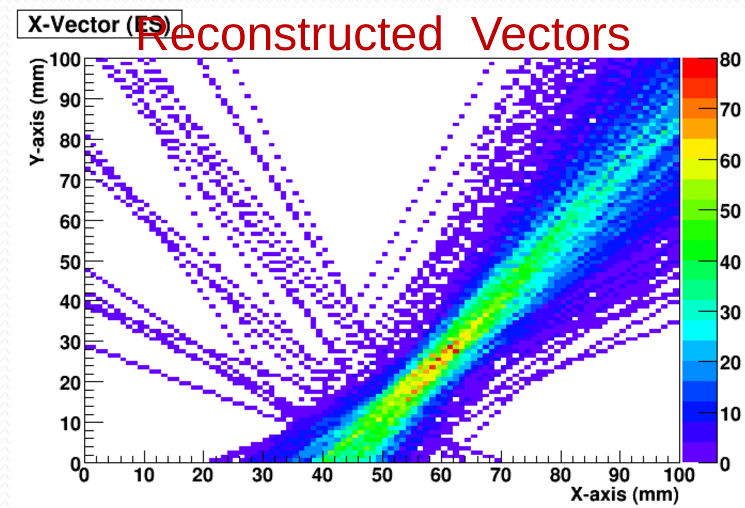
Preliminary Bench-Top Measurements

Reconstructing Low Energy Sr90 β⁻ Tracks

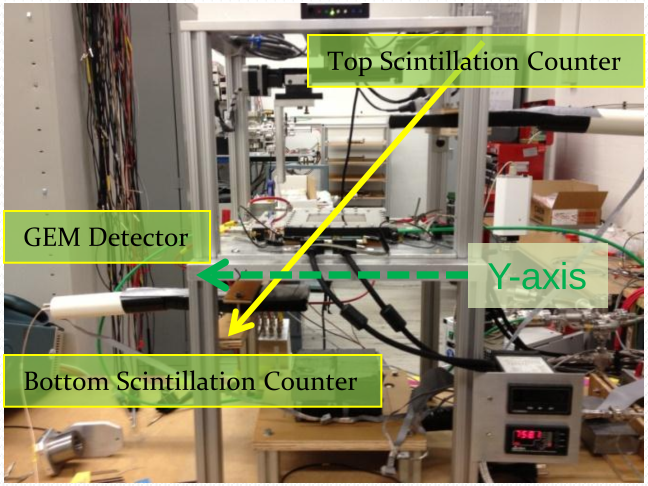




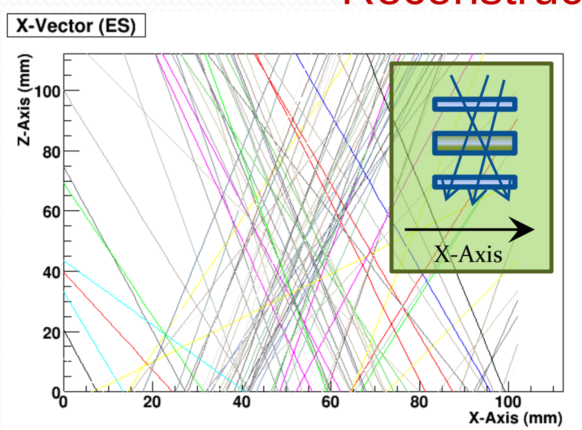
- GEM trigger doesn't provide precise timing, so rely on ability to measure the first pad fired as a measure of t_zero
- Det. requirements: high gain, low noise, low diffusion gas
- Use timing from ADC to reconstruct z-coord. of track

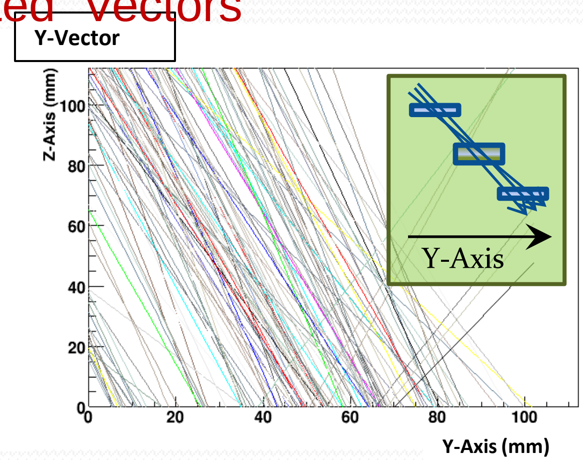


Reconstructing Cosmic Ray Tracks



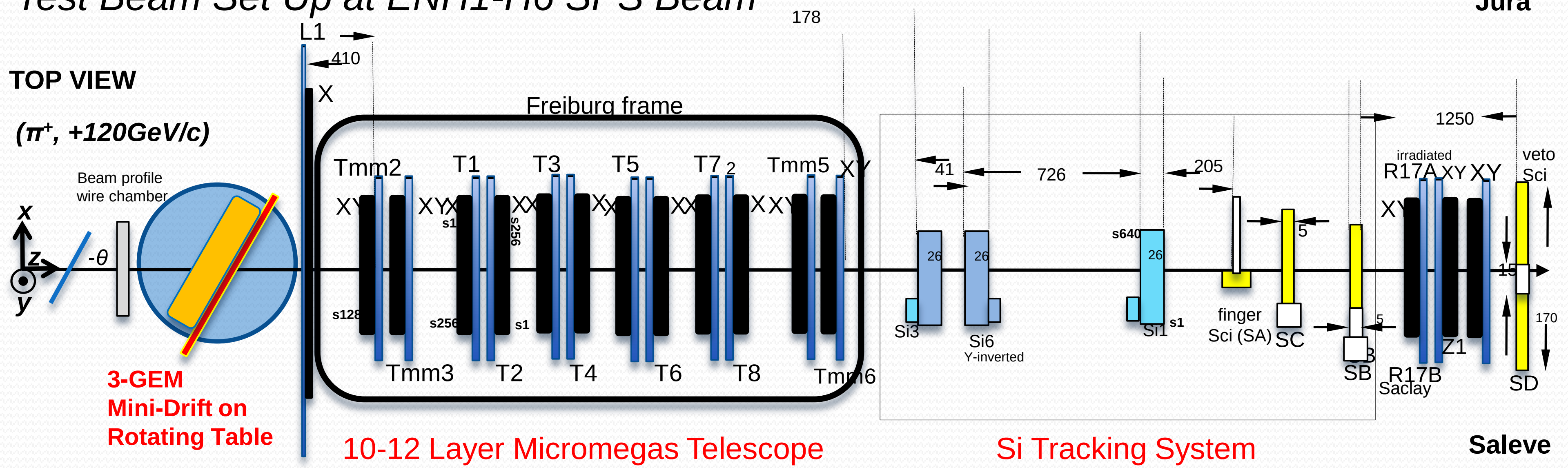
Reconstructed Vectors

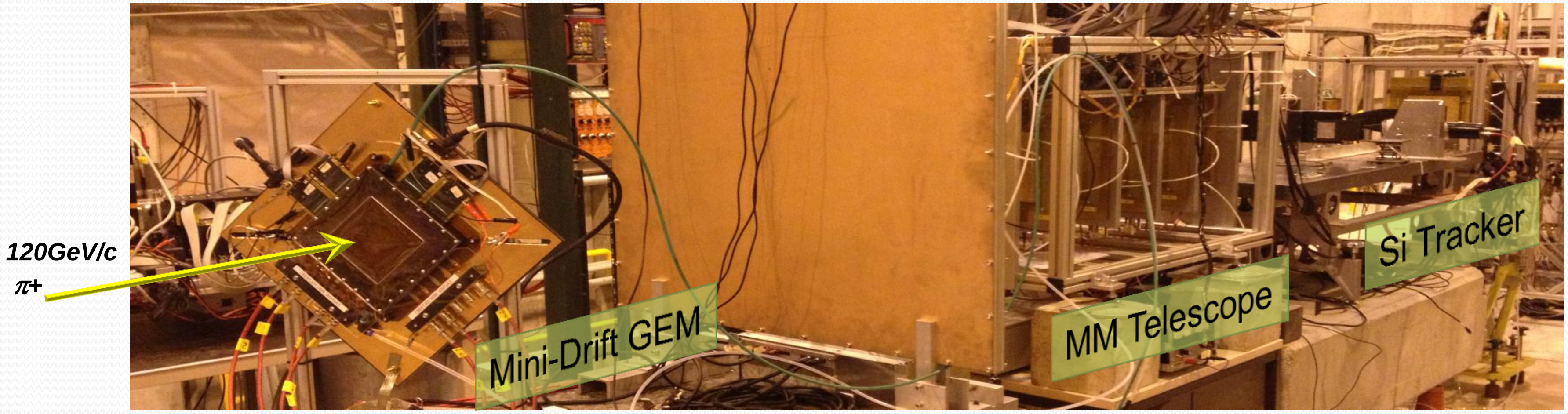




Measuring Tracks at CERN Beam Test

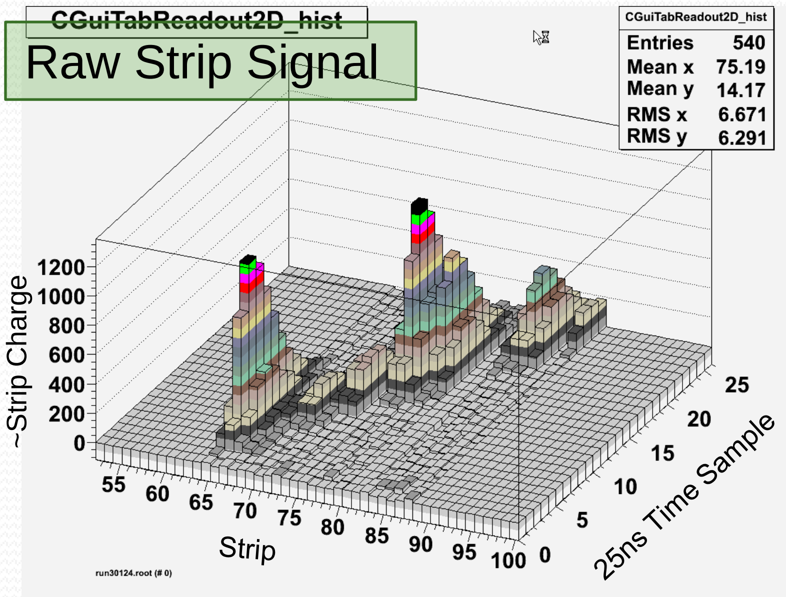
Test Beam Set Up at ENH1-H6 SPS Beam



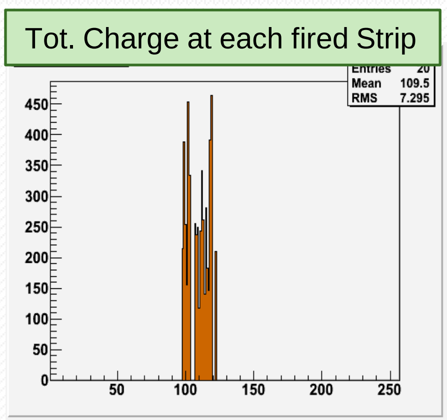


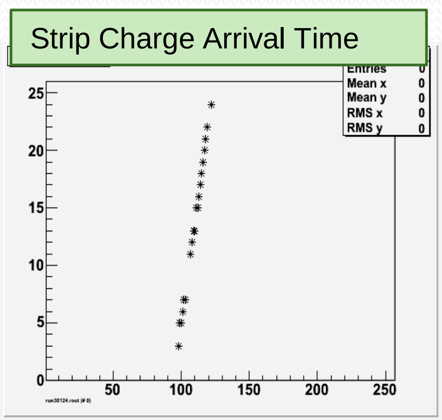
Beam Test Results (40 deg. Tracks)

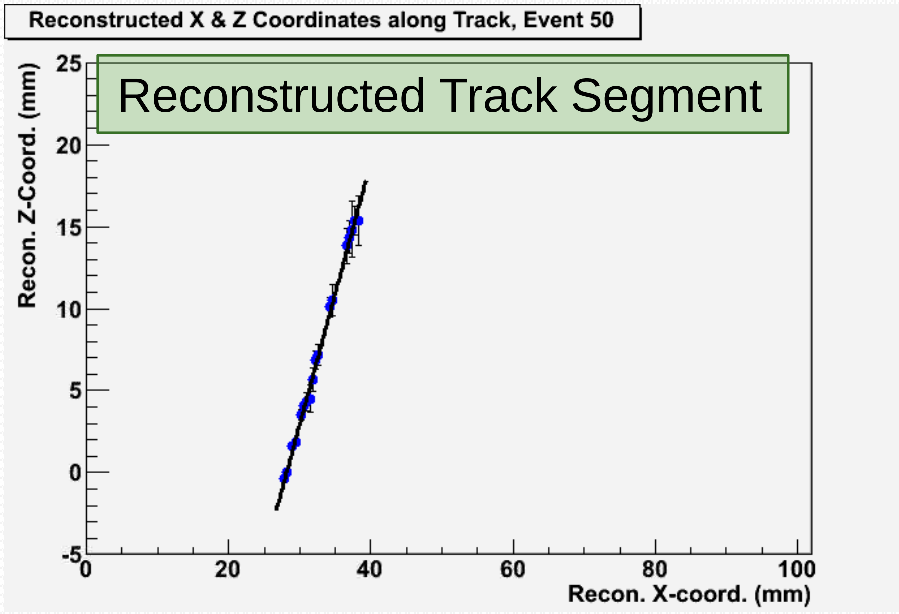
Reconstructed Track from 1 Event



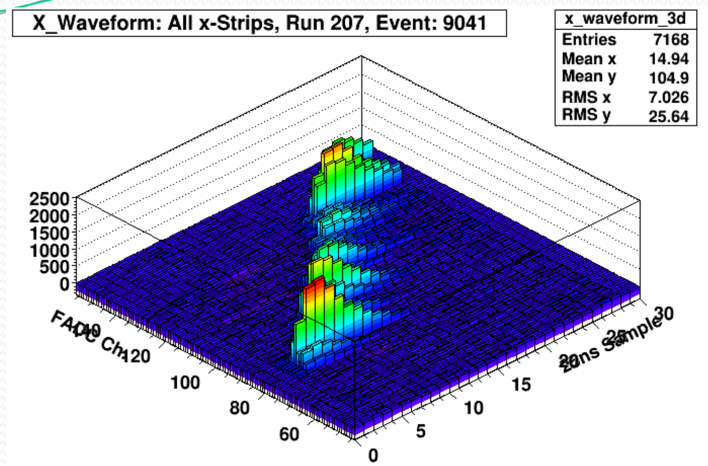
- ❑ The charge arrival time for each strip is determined by the time profile of the raw signal. The z-coord. is then reconstructed by taking the product of the arrival time and the drift velocity of the detector gas.
- ❑ The x_coord. is taken as the center of each strip.
- ❑ The vector is determined from a linear fit to the reconstructed (x, y) pairs for the event.



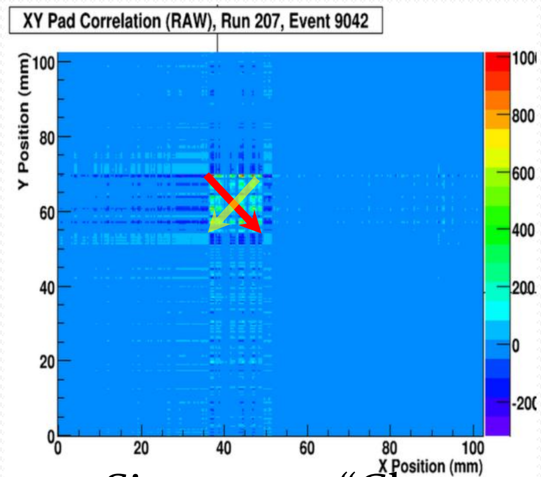




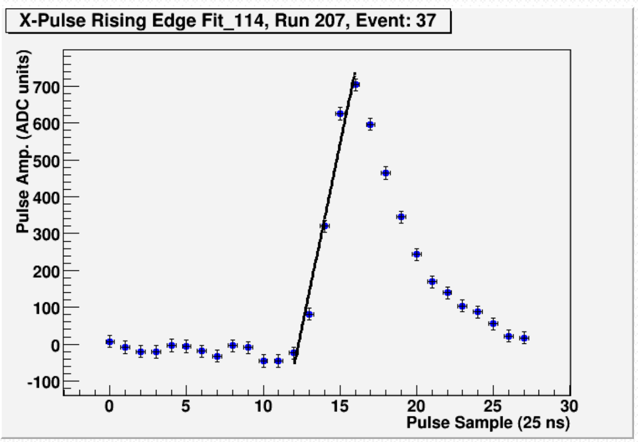
Data Processing

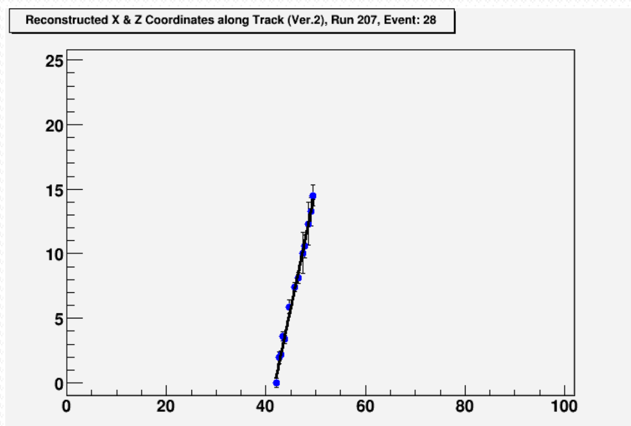


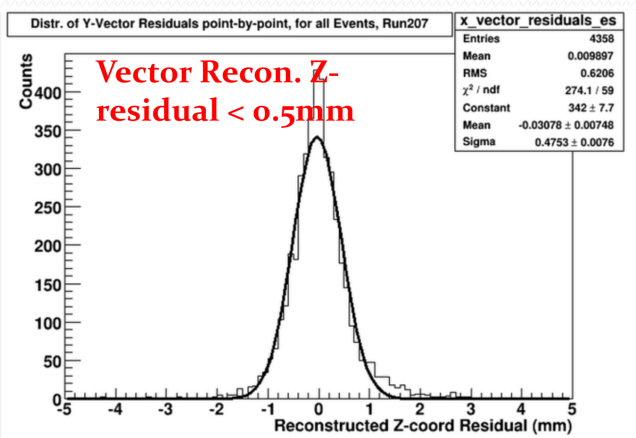
Raw Data: Waveforms in Time



Vector Signature: “Charge square”







• Linear Fit to determine arrival time = x-int.
•30 samples x 25ns = 750ns window

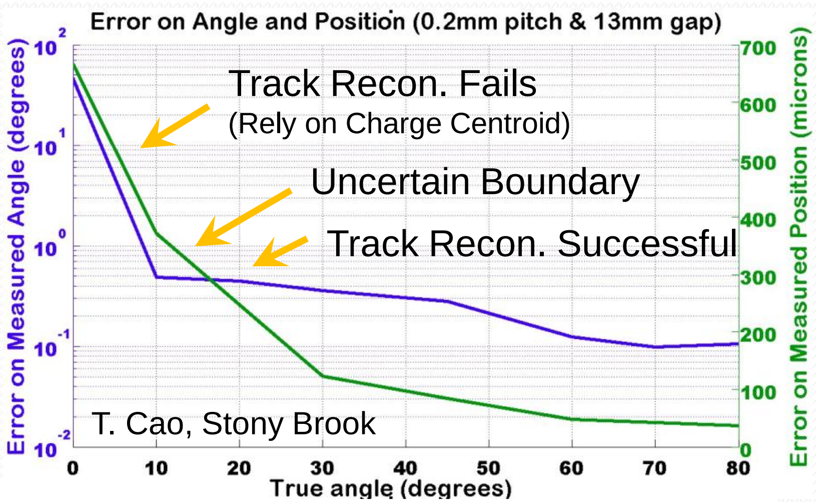
Vector Recon:
•X -coord. = middle of pad
• Y-coord. = drift time * Drift Vel.
•Fit (x,z) points to line

Propagated Errors:
Angle: ~+/-18mrad
Charge arrival time: ~+/-1.8ns

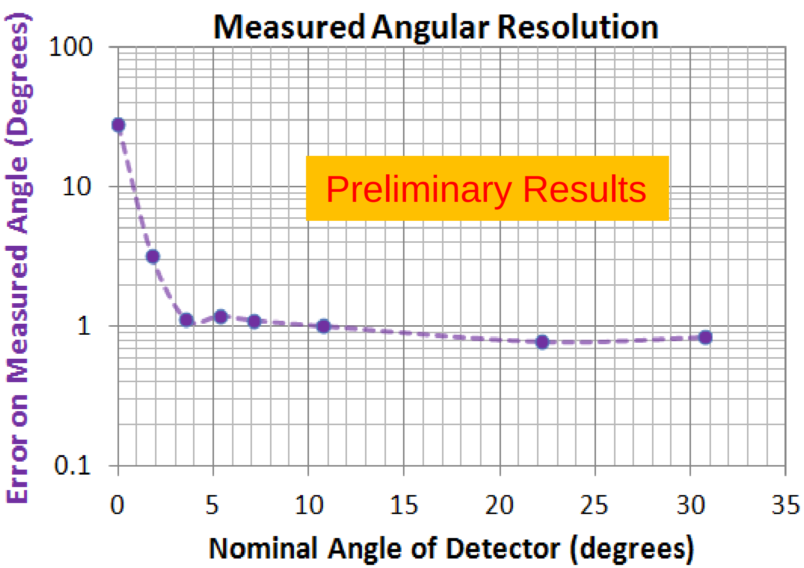
Angular Resolution

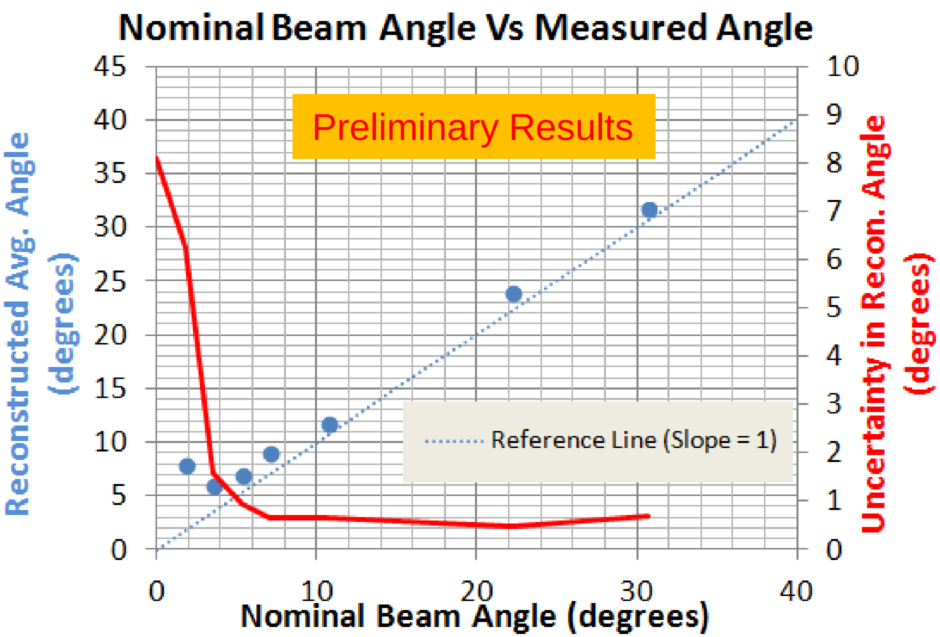
A first look at the Angular Resolution

MC Simulation of Angle and Position Resolution



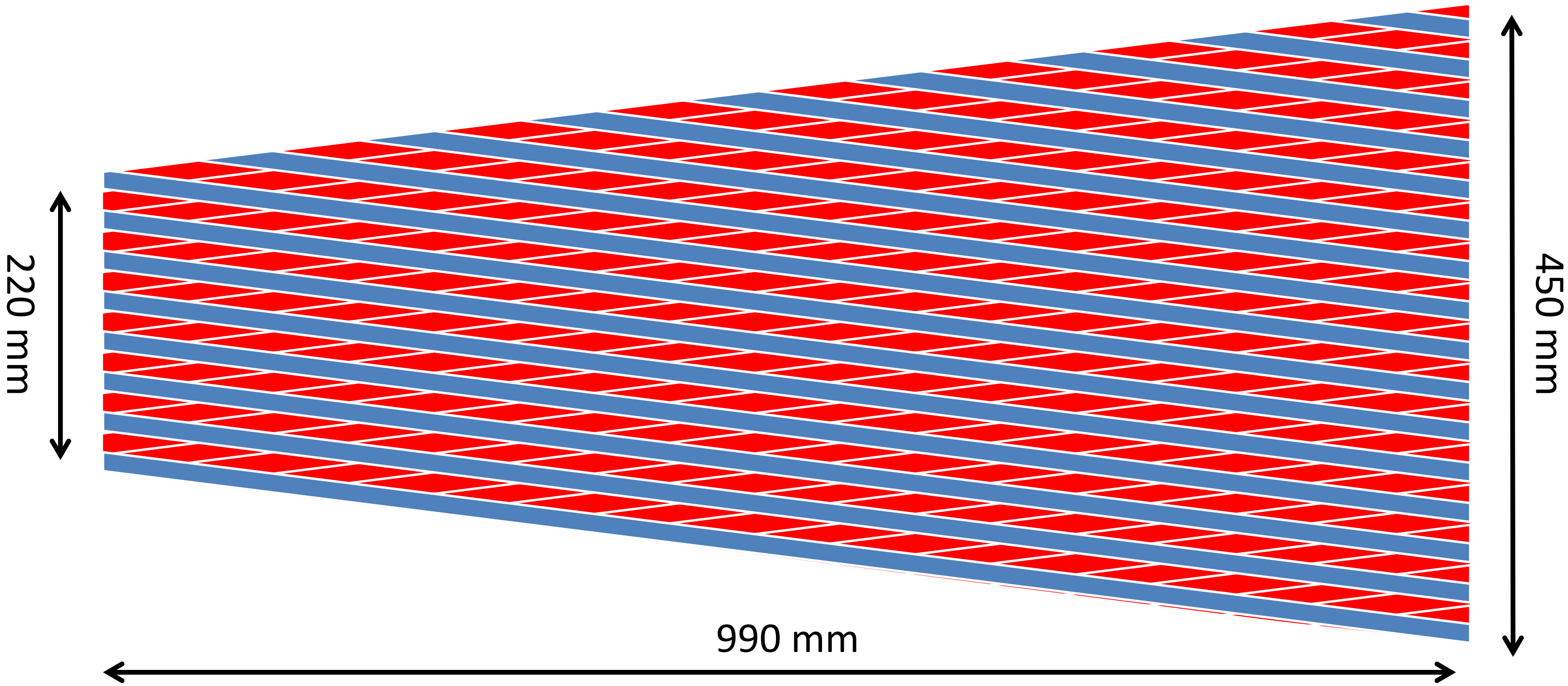
- ❑As a first attempt to determine the angular and position resolution, we do so without the aid of a reference track, determined by the high precision reference detectors within the beam test set up.
- ❑The angular resolution is determined here by simply taking the spread in the distribution of the reconstructed vector angle. This is known to be a reasonable approximation since the beam divergence is minimal.



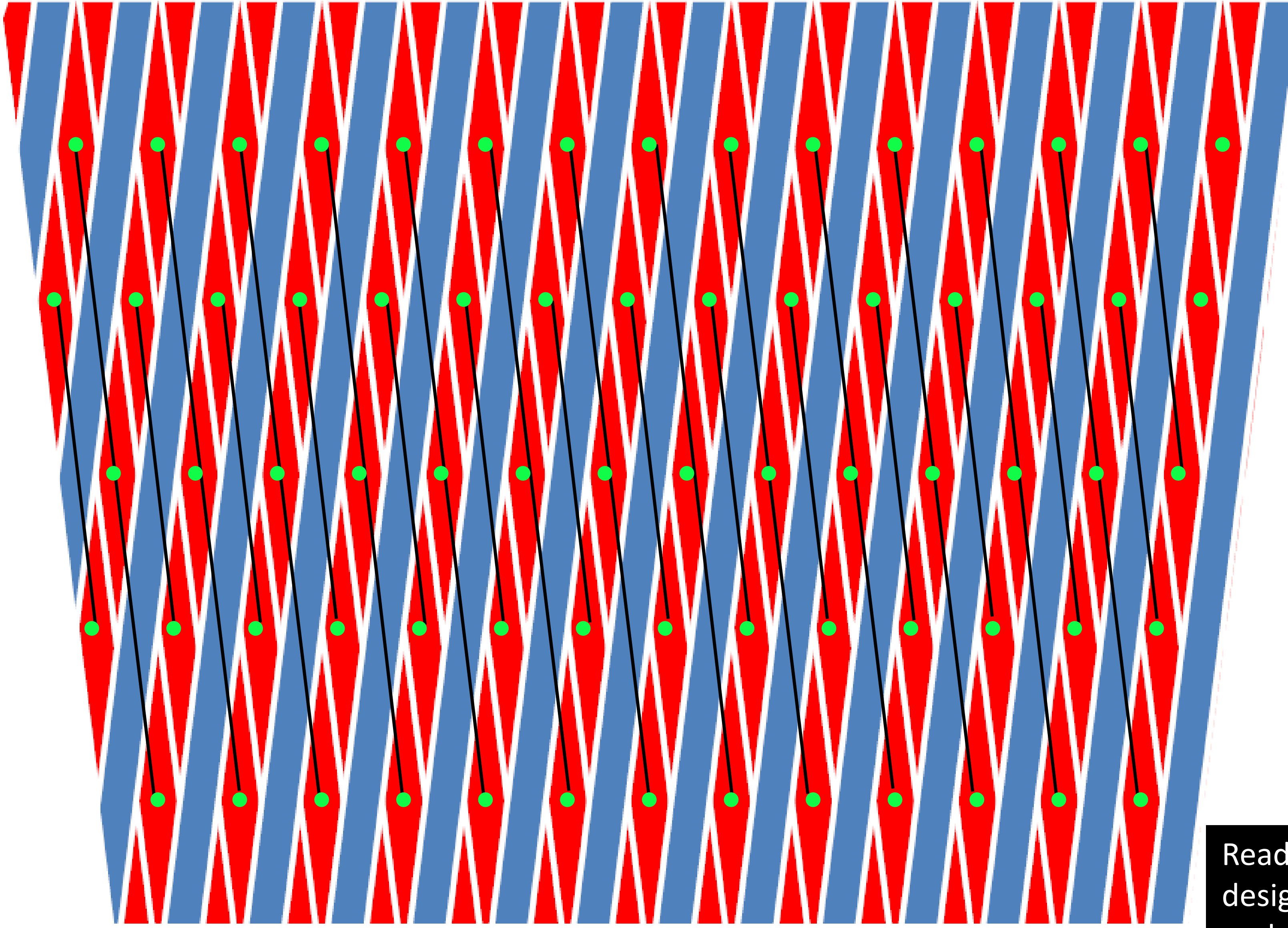


2D stereo angle Readout for UVa EIC Large GEM chamber

- Suggested readout scheme:
  - a 2D readout optimized to get high accuracy in the **ϕ** coordinate, lower but sufficient resolution in the **r** coordinate.
  - each set of stripes parallel to one of the radial sides of the module: strip pitch is 0.6 mm.
  - Issues: High capacitance in long readout strips; will signal-to-noise be an issue ?



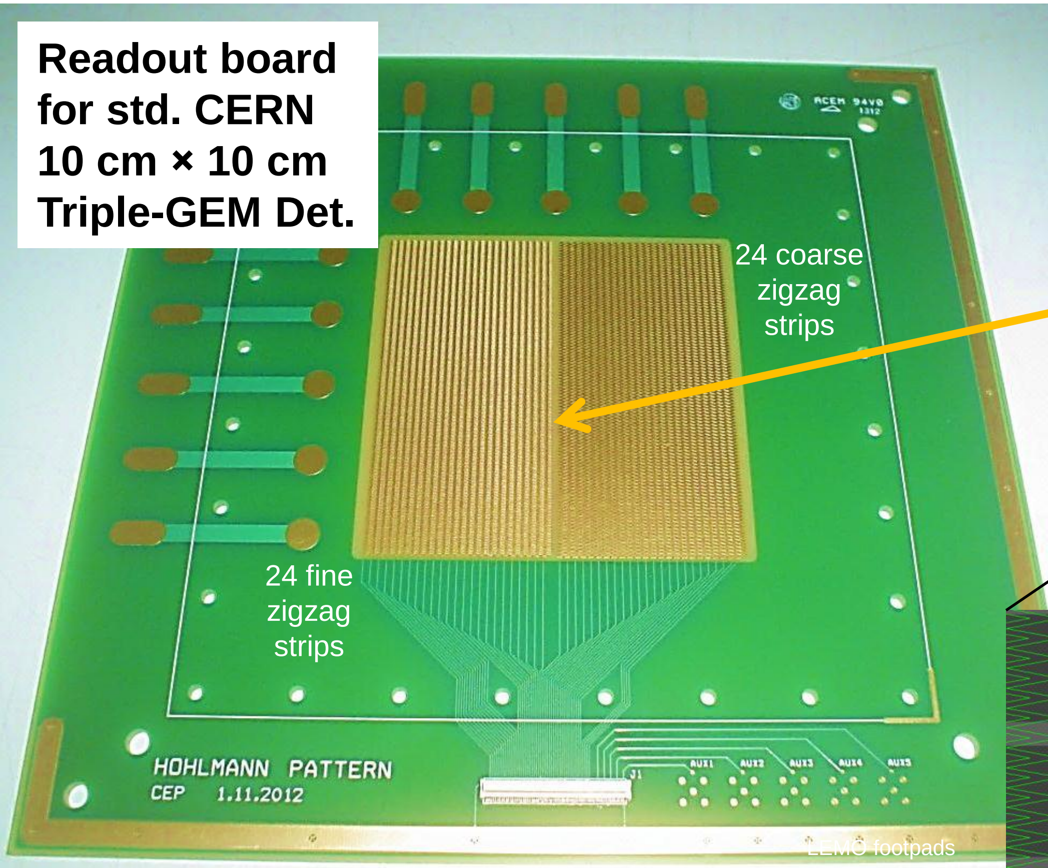
2D stereo angle Readout for UVa EIC Large GEM chamber

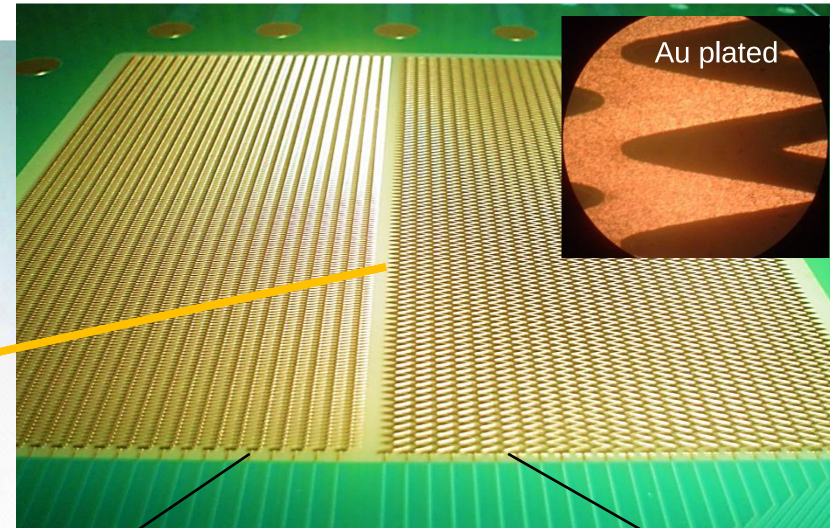


Readout plane design is currently underway

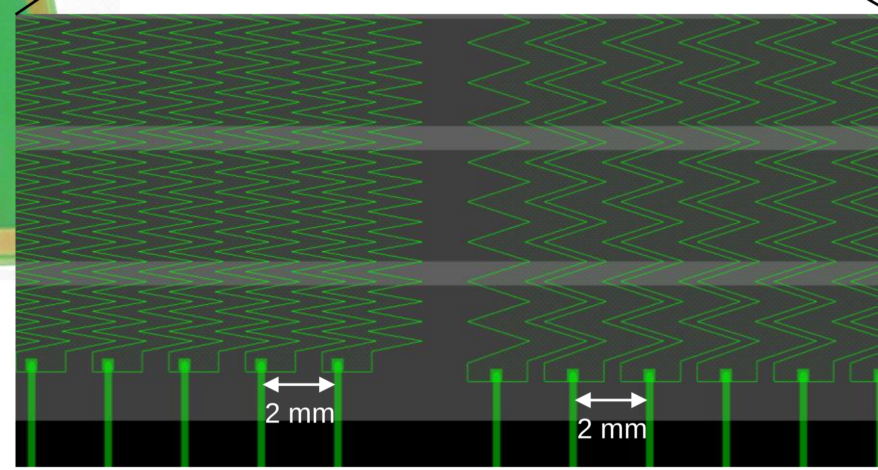
Zigzag strip readout board

Readout board for std. CERN 10 cm × 10 cm Triple-GEM Det.





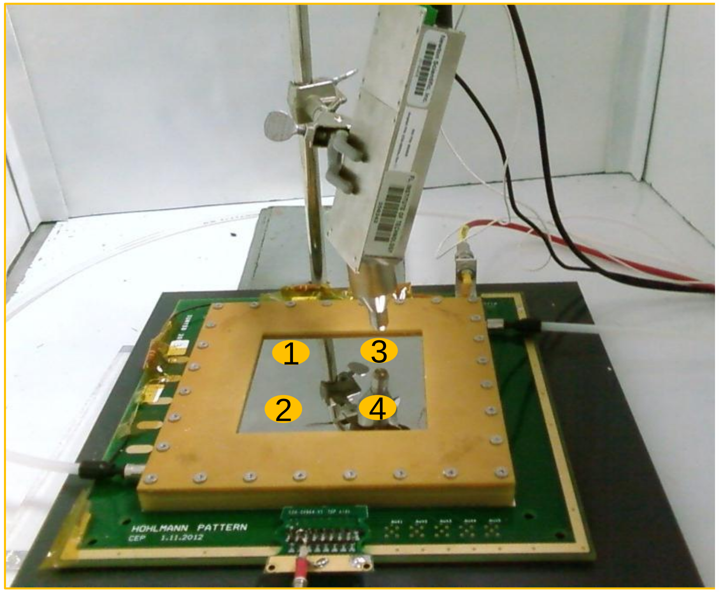
2 sets of 10cm zigzag strips with different zigzag pitch (along strip)



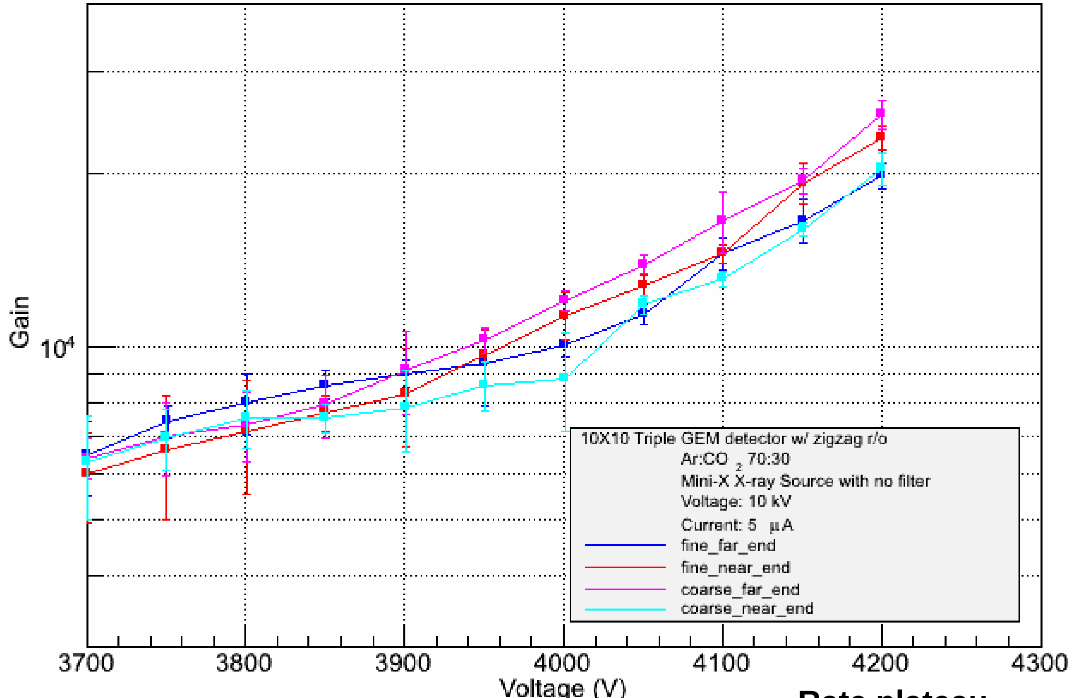
CAD Design by C. Pancake, Stony Brook

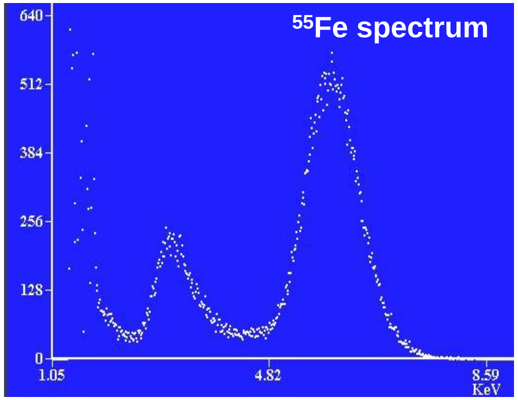
EIC Zigzag-GEM bench tests

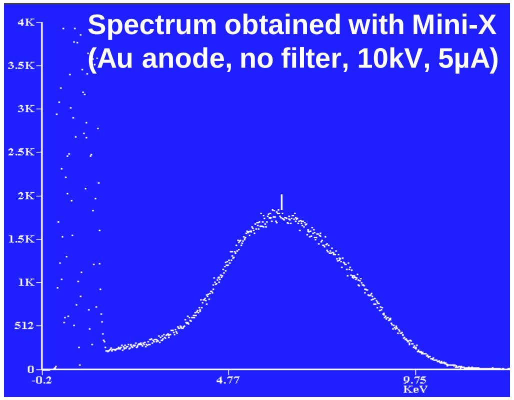
"Mini-X" x-ray source inside 3' × 2' × 2' lead-shielded box (procured / constructed with funds from this project) irradiating 10cm × 10cm Triple-GEM with zigzag readout



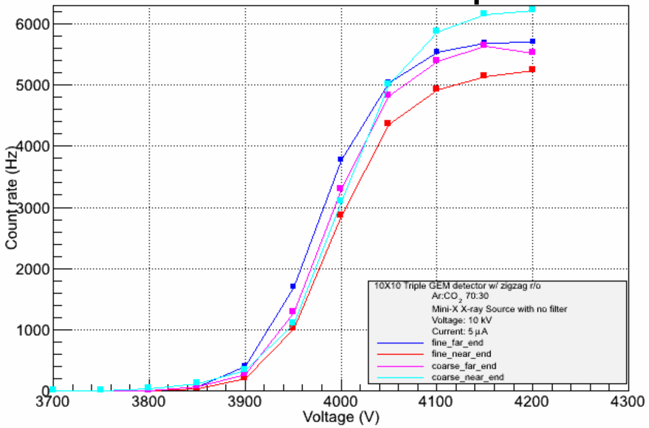
Gas gain measurements at four spots







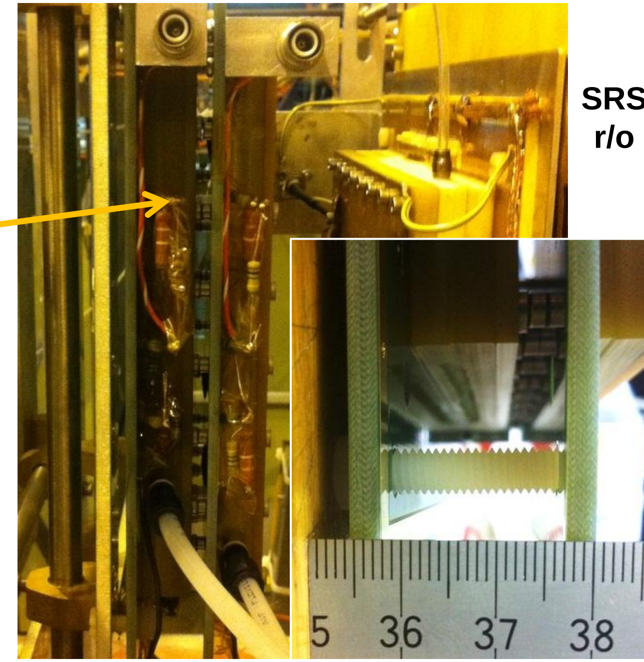
Rate plateau



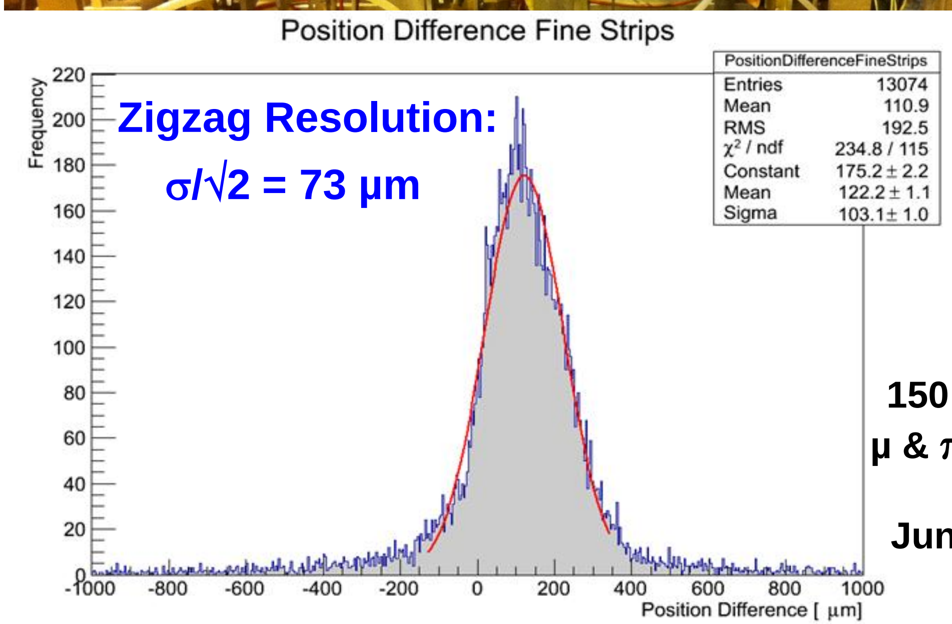
V. Bhopatkar

2012 RD51 beam test @ SPS

2 zigzag detectors mounted in a stack



SRS r/o

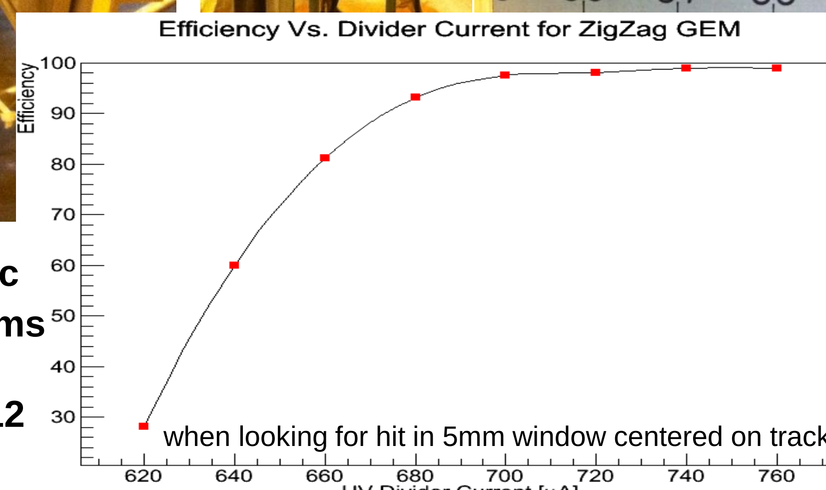


Zigzag Resolution:

$\sigma/\sqrt{2}$ = 73 μm

150 GeV/c
μ & π beams

June 2012



when looking for hit in 5mm window centered on track

Current zigzag GEM effort

- **Setting up gain uniformity measurements using Mini-X x-ray and Scalable Readout System (SRS)**
  - noise is low for zz strip r/o (few ADC counts pedestal width)
  - triggering on signal from bottom of GEM 3 established
- **Designing larger pcb with zigzag readout strips for “S4” 30cm × 30cm Triple-GEM**
  - Strip pitch = 30cm/128 = 2.3 mm to read out entire 30cm width of GEM detector with a <u>single</u> APV25 hybrid (128 ch.)
  - Planned zigzag strip length: 10 cm
  - Additional sections with radial zigzag strips on same pcb to test for use in a larger trapezoidal GEM
  - Currently slow going due to inexperience with pcb design work (undergraduate); expect major boost from post-doc hire

EIC

Plans

Florida Tech

- Transfer know-how with S4 GEM to EIC forward tracking colleagues from U. Virginia: Kondo Gnanvo to visit Fl. Tech Dec 18-21 for a training session on S4 construction
- Test S4 GEM response uniformity w/ x-ray source & SRS
- Finish design of zigzag r/o board for S4 GEM and get a few boards manufactured
- Develop a simulation of zigzag strip readout in ANSYS and GARFIELD
- Test zigzag GEMs in magnetic field (bench top, test beam?) to check impact on spatial resolution
- Construct a ~ 1m × 0.4m trapezoidal S4 GEM
- Design and test zigzag pcb for the 1m × 0.4m trapezoidal S4 GEM

3-coordinate GEM readout

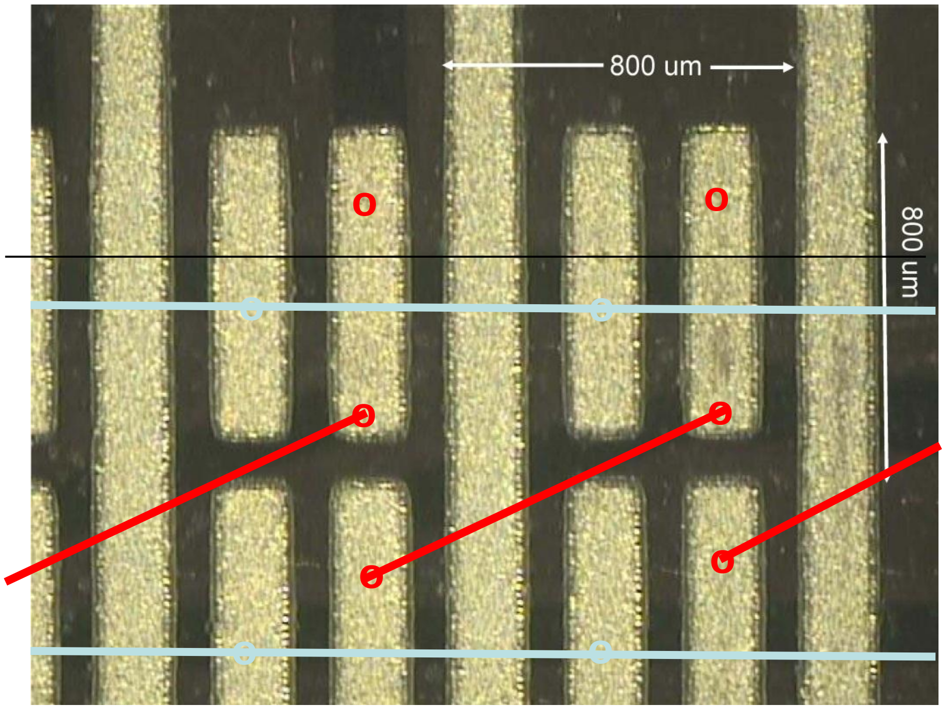
For a given track density, 3-coordinates from one chamber will allow larger chamber sizes which will reduce readout costs and material.

Extension of the 2-coordinate strip/pad readout. Add another set of pads connected diagonally (red, vias and traces on back).

We have 800 mm pitch boards, chamber parts in hand

RD51 SRS readout system ordered last February is finally available at CERN so we hope to begin all the "usual" tests early next year.

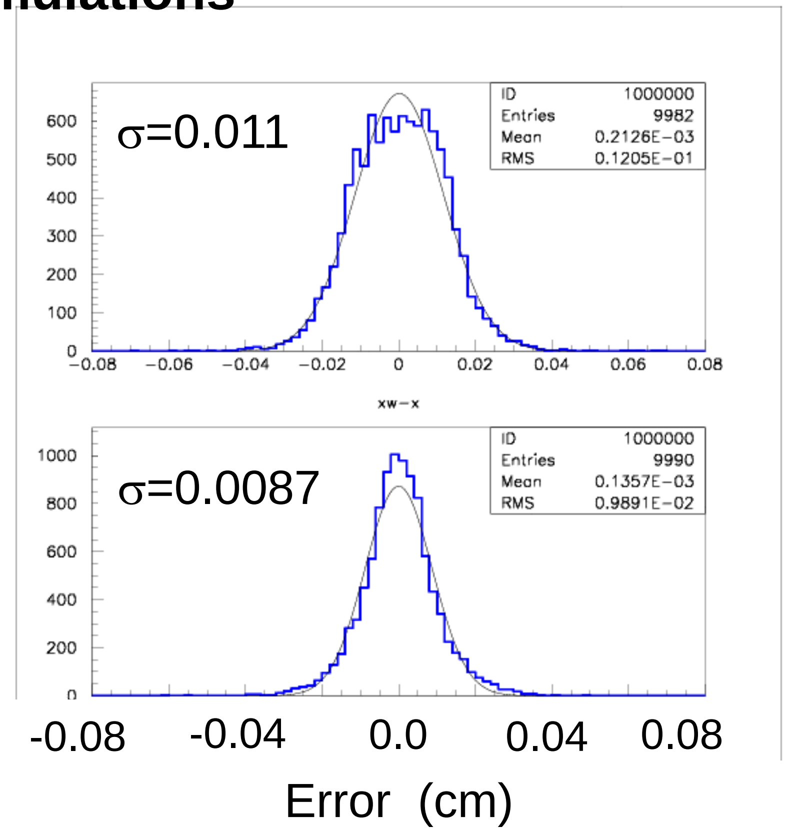
Proposing a run in the SLAC test beam next spring



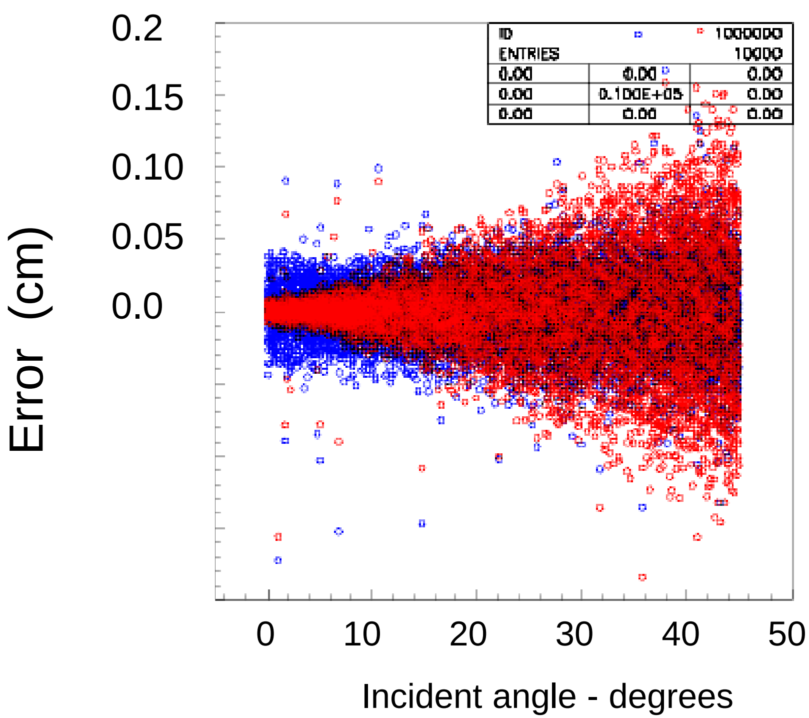
GEM detector simulations

We have developed a detailed simulation for GEM structures over the past year and have been testing it against 2-coordinate chambers

It is already showing interesting results for analysis algorithms.



Resolution for 800 um pitch and 600 um pitch chambers from simulation



Resolution vs. incident angle using charge weighted average of hit strips and average position of hit strips

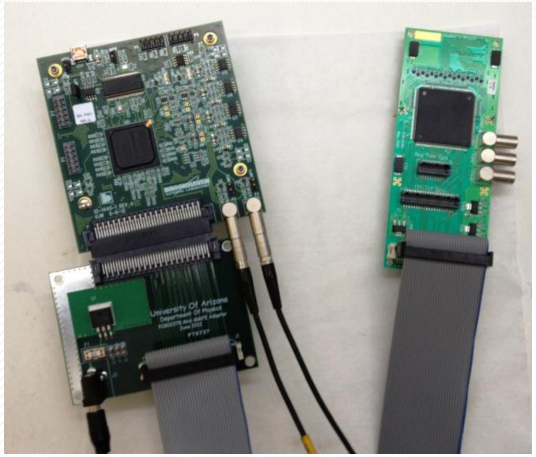
Plans for the coming year

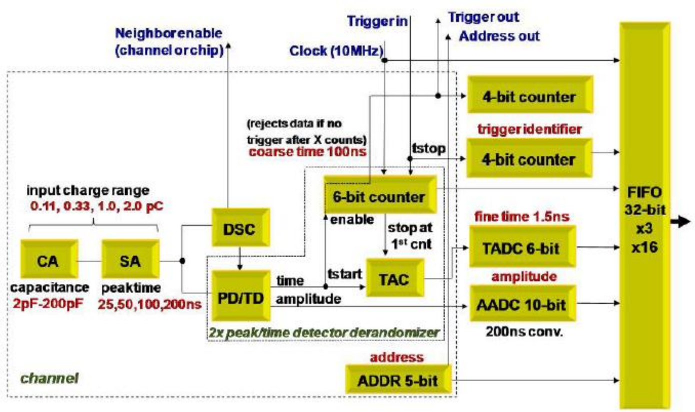
•Commission SRS readout system – early 2013

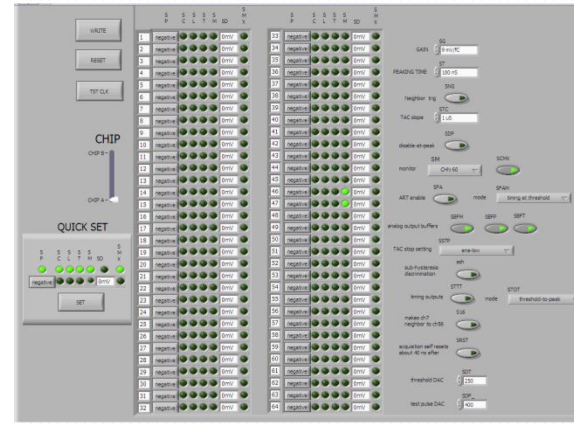
•Test 3-coordinate chambers with 55Fe source and cosmic rays. Measure basic parameters (gain, cross talk, charge sharing, upper limit on resolution, lower limit on efficiency) Winter/Spring 2013

•Run chambers in test beam (measure resolution, resolution vs. incident angle, …) Spring/summer 2013

GEM Detector + New VMM1 Readout





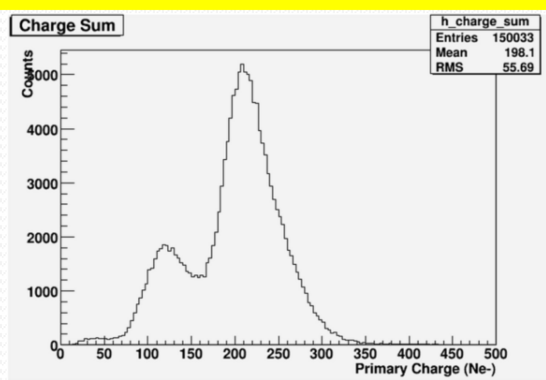


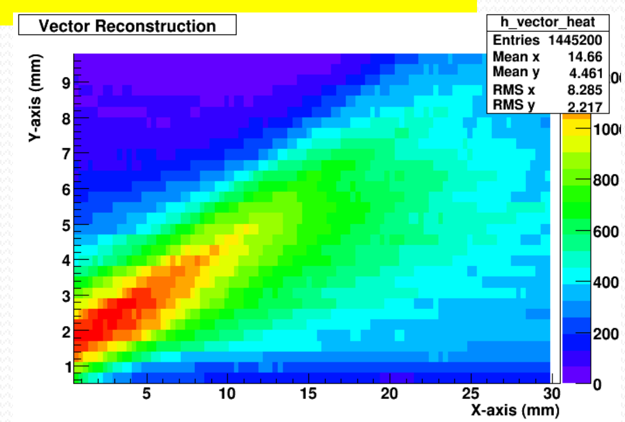
VMM1 →FEC →USB→PC

VMM1 Labview Control panel

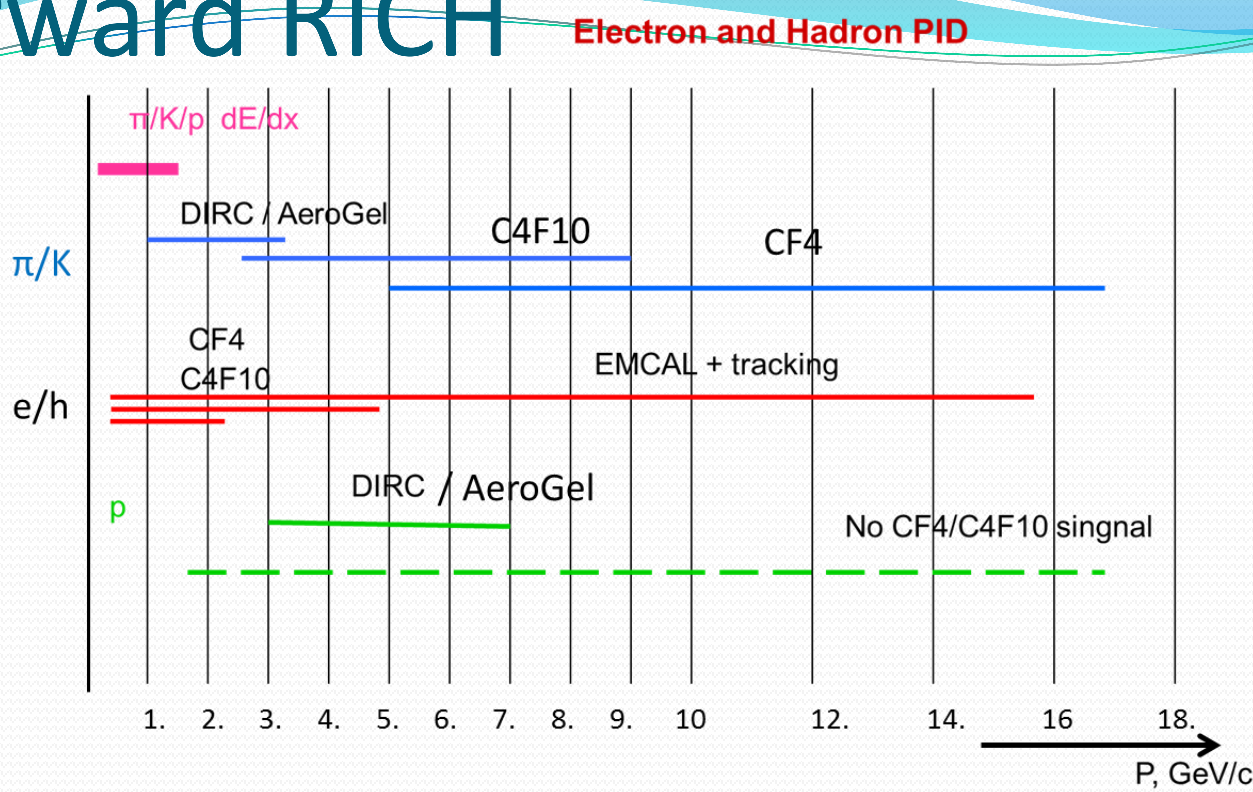
•Peak sensing ASIC that provides charge amplitude, and peak-time with minimal time walk
•Programmable electronic gain, memory depth (we use 1usec)
•Records only pads with charge above threshold
•Labview interface allows for Plug n' Play
•Despite only spending a day's worth of time with the chip, we were able to take some quality data with relative ease

Preliminary Results (64 ch.):
- Measured Fe55 spectrum
- Measured Sr90 vectors at ~35°



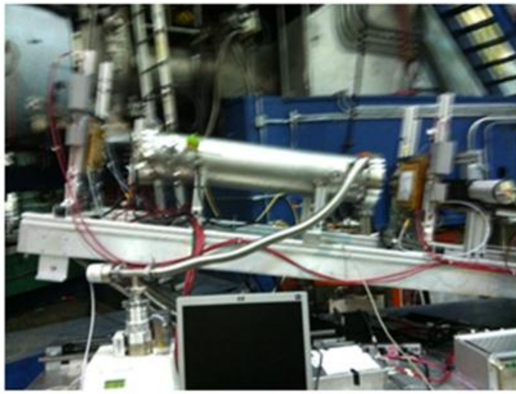
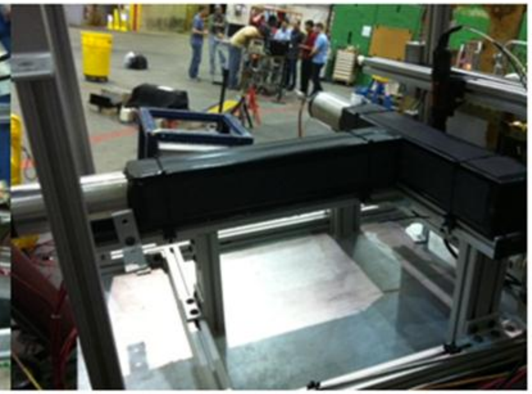
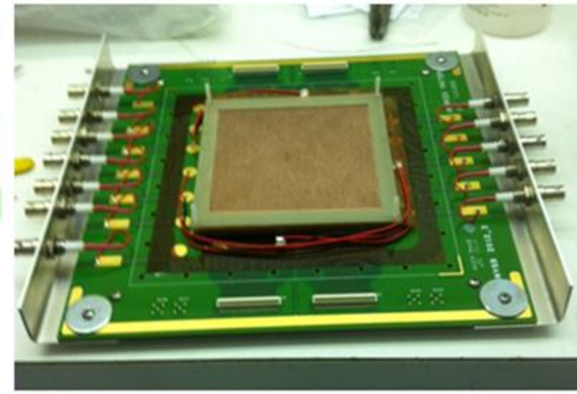


Forward RICH

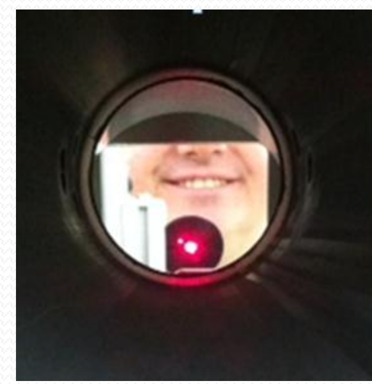


- RICH particle ID involves a limited dynamic range of momenta set by gas index of refraction.
- The highest momenta rely on the lowest n.
- Our R&D targets the highest momenta with a CsI photo-cathode RICH.
- Major Issue: Reflectivity of mirrors deep in the UV.

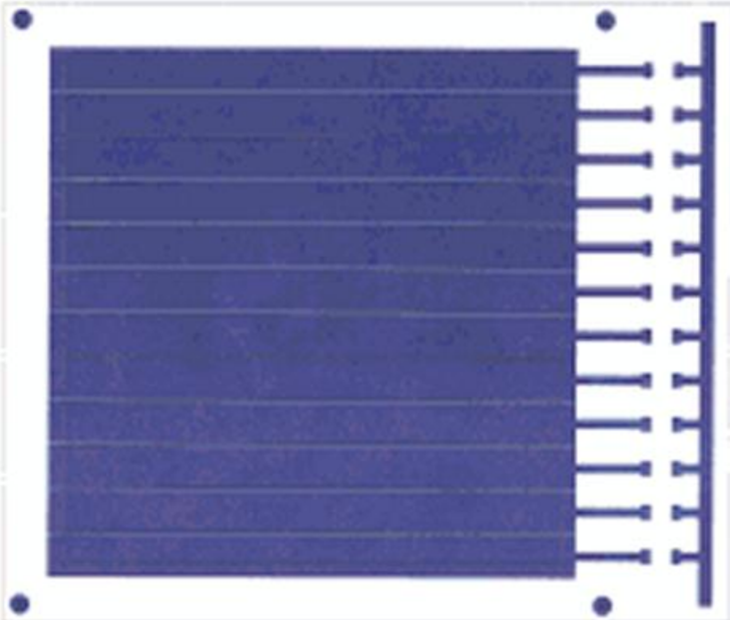
Forward CsI RICH Progress.

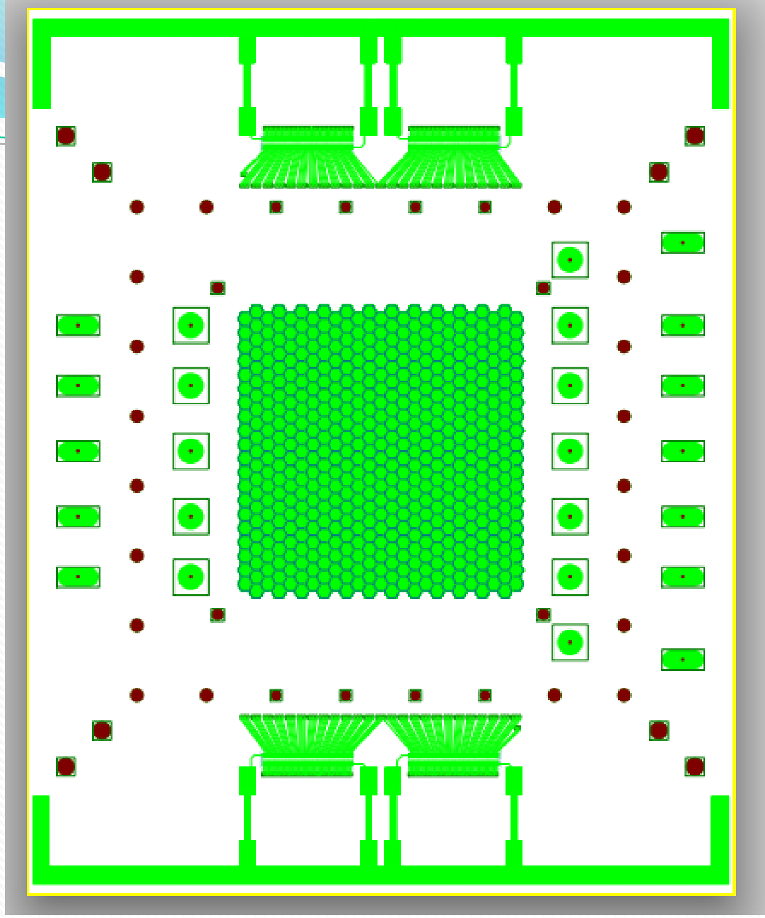




- J-Lab tests disappointing:
  - 2 million events w/ 15 tracks…none electrons.
- Test beam requested at SLAC March 2013



Changes for SLAC

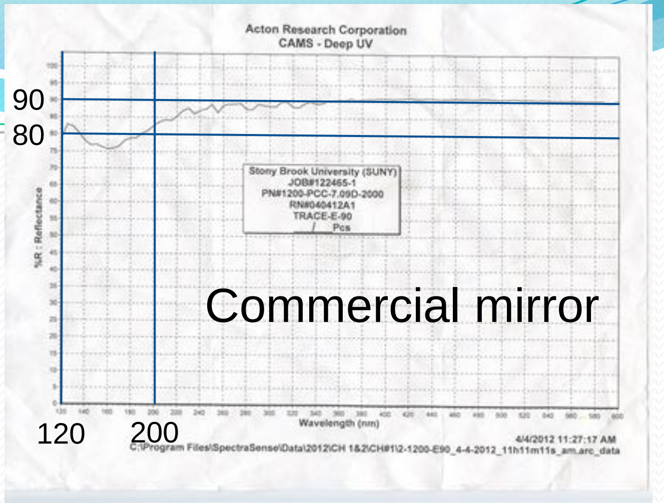




- New GEM foils…multiple strips like PHENIX.
- Second pad plane…hexagons to see rings.
- New trip detection system:
  - Capacitive coupling off resistor chain.
  - Integrated with PHENIX HBD HV relays.

Mirror Developments

- Cherenkov photon yield primarily at small λ.
- Deep UV mirrors use 250 A° MgF_2 overcoat to act as dielectric mirror.
- Plans:
  - Year 1: Develop in-house manufacture of small mirrors.
  - Year 2: Scale up to use Big Mac
- First in-house mirror made!
- Reflectivity tests pending at BNL.

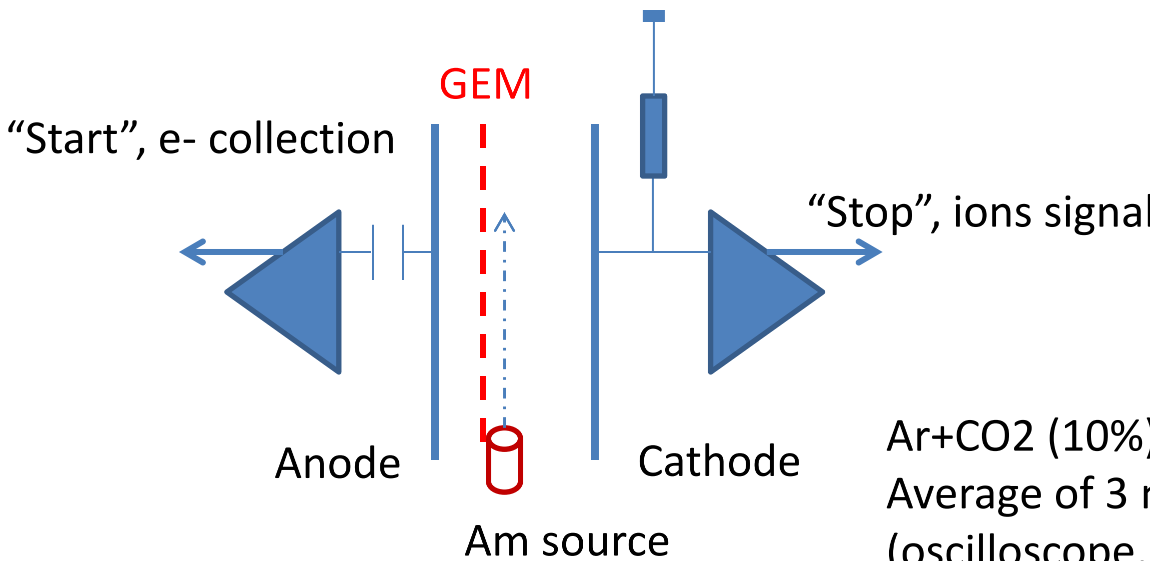


Summary

- Despite funding division across fiscal boundary, we have significant progress on all fronts:
  - Postdoc long/strong list of candidates.
  - TPC/RICH
  - Forward Tracking
  - Forward HBD
- Multiple options in parallel development.
- Expect continued progress in the coming year.

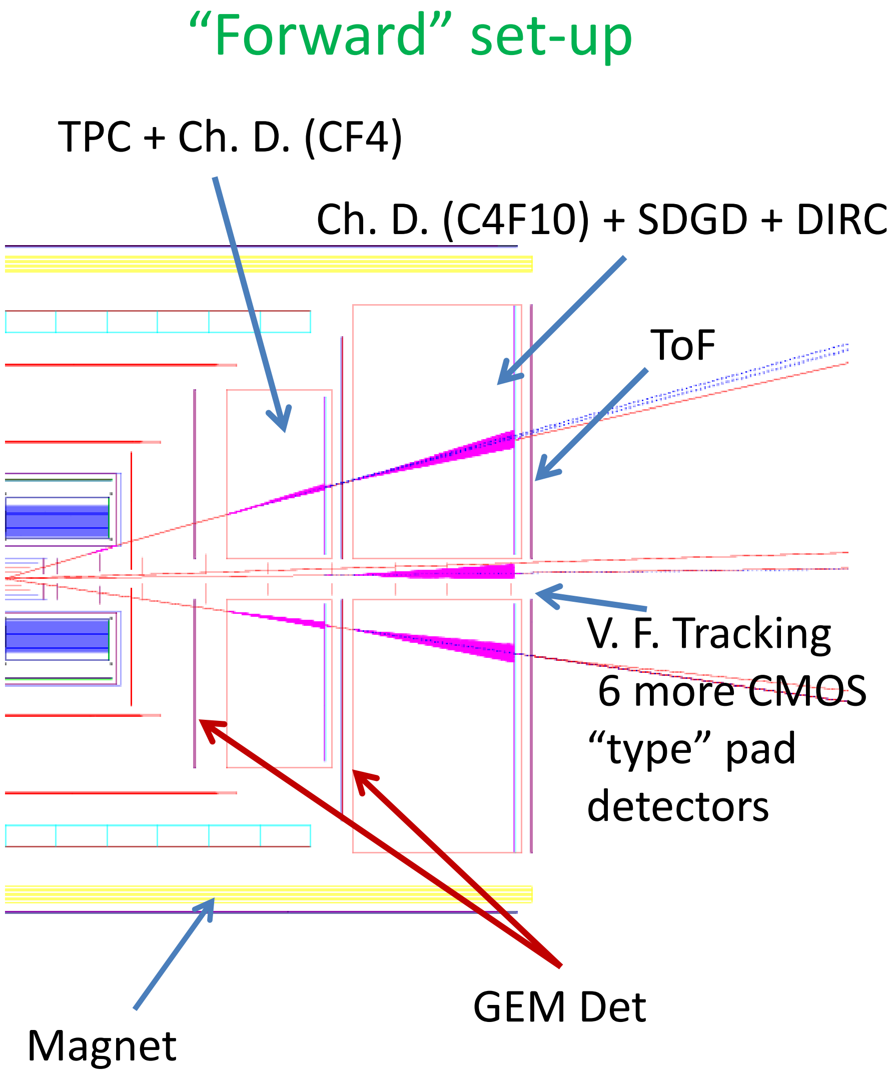
Backups

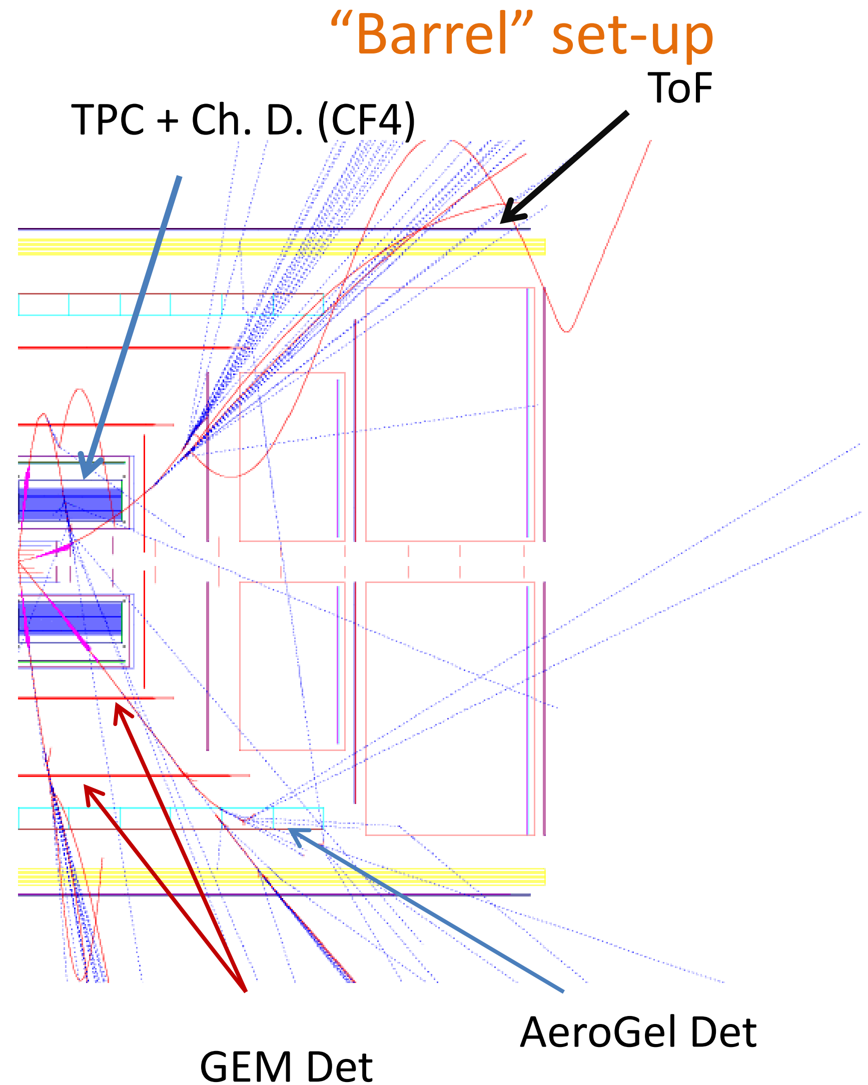
- Setup to measure mobility of positive ions
- Single GEM foil is working as gas amplification for α–particle (Am^{241}) primary ionization



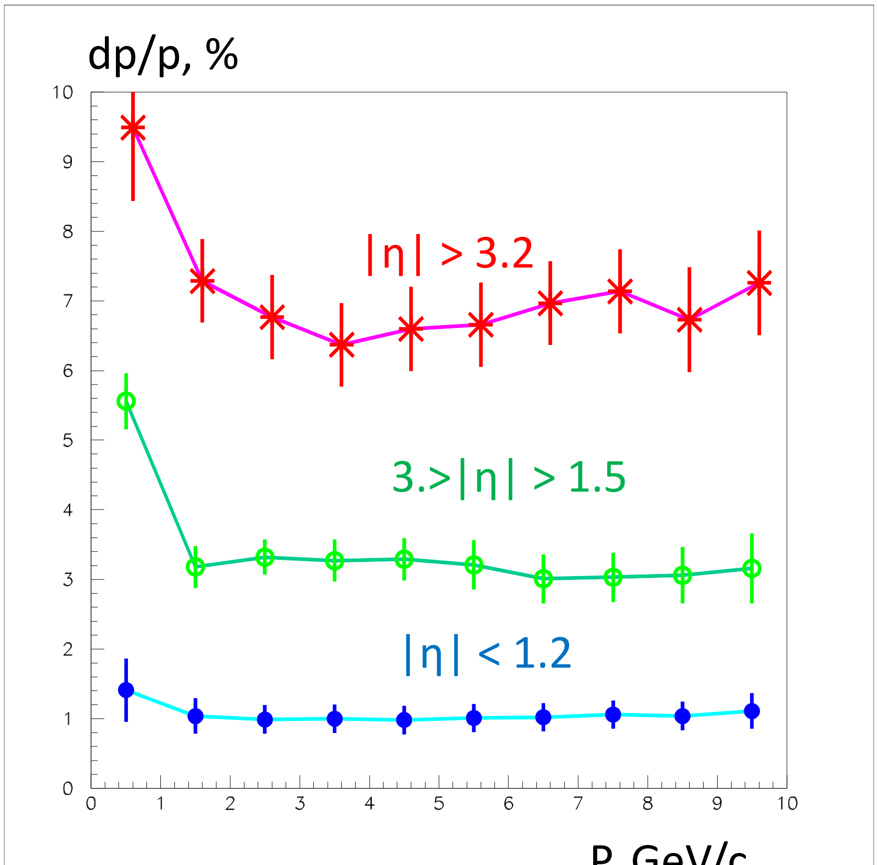
Ar+CO2 (10%)
Average of 3 measurements
(oscilloscope, no calibration)
for different E-fields in drift region :
<Mobility> ~ 1.04 cm2 V-1 sec-1

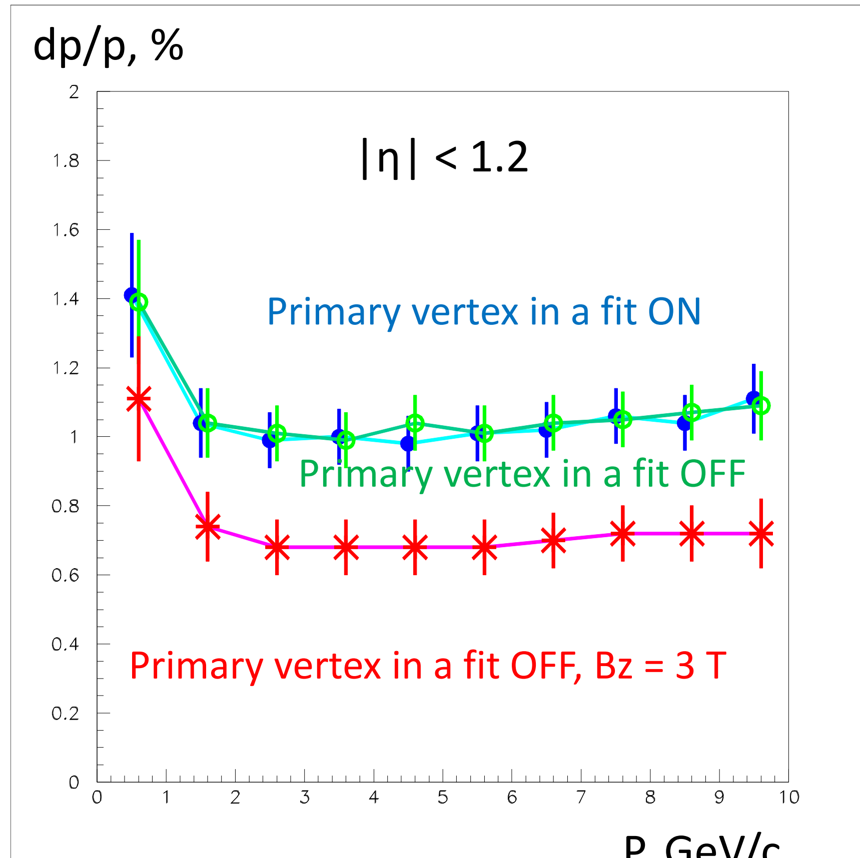
Set-up in simulation; SC magnet Bz=2. T, R=1.5 m, dZ=2.5 m; (EMCALs not shown)





dP/P performance (%); one π^- / event; Bz = 2. T



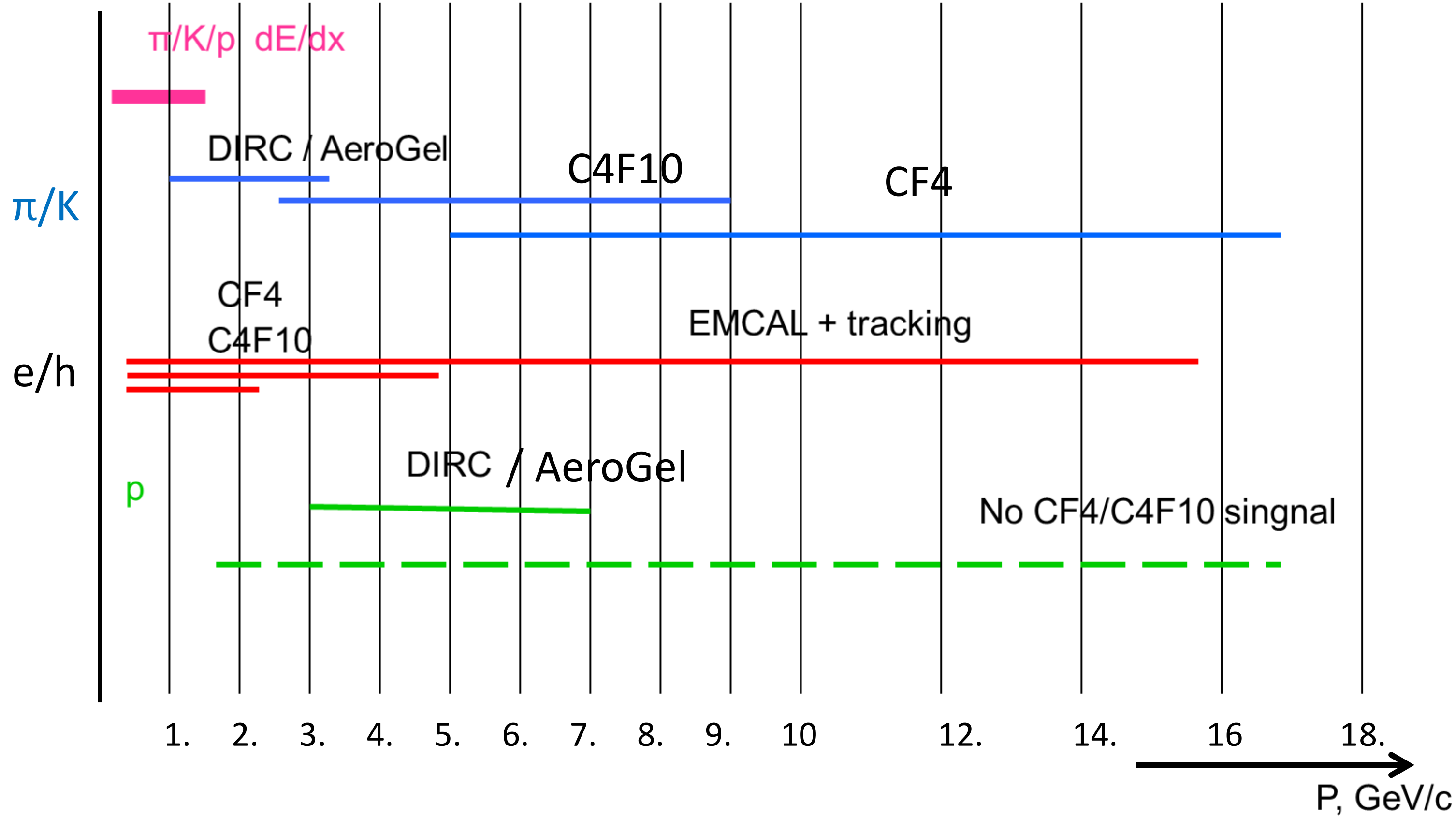


PiD performance for particle P (GeV/c)

	dE/dX	DIRC/Aerogel	C4F10*)	CF4	EMCAL
π/K	0-1. (1.5)	1-3 (1-4)	2.5-9	5 – 17	
e/h	0-0.2	< 0.5	<2.5	< 5.	> 0.5
p	0-1.5	3-7	< 17. (no signal)	<30 (no signal)	

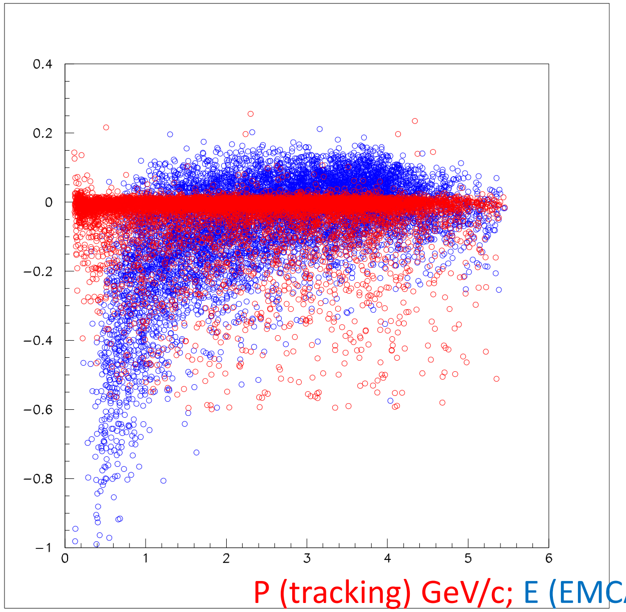
*) Forward only

Electron and Hadron PID

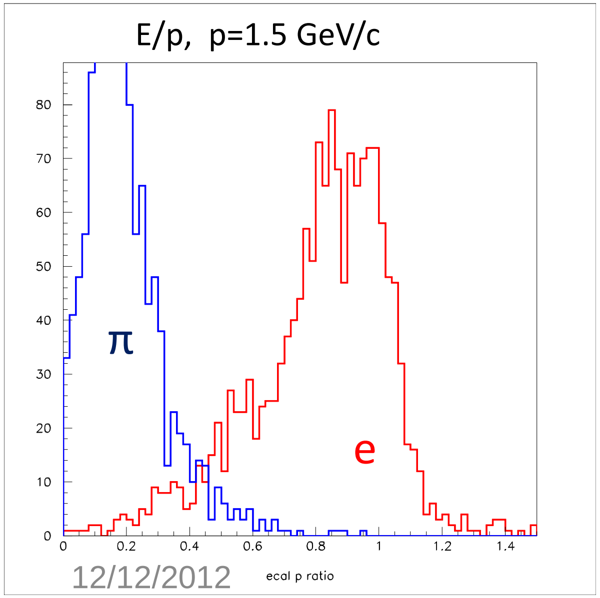


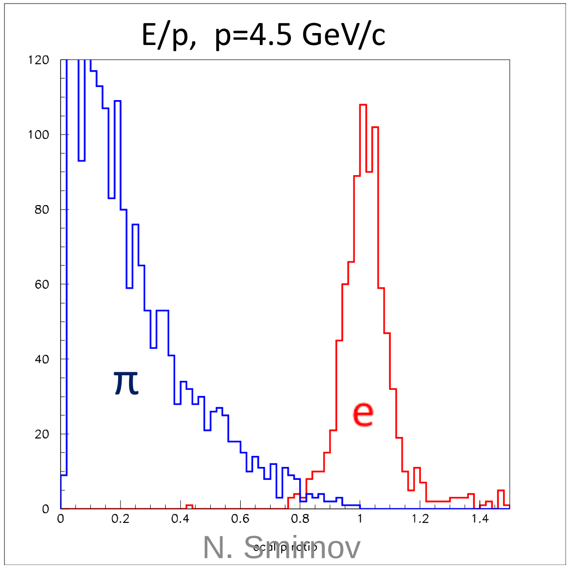
Response to electrons (tracking –EMCAL)

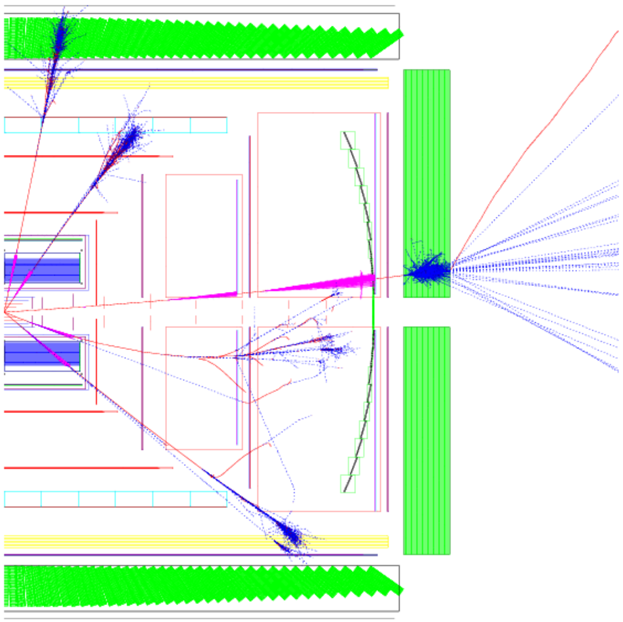
dp/p; dE/E



P (tracking) GeV/c; E (EMCAL); GeV







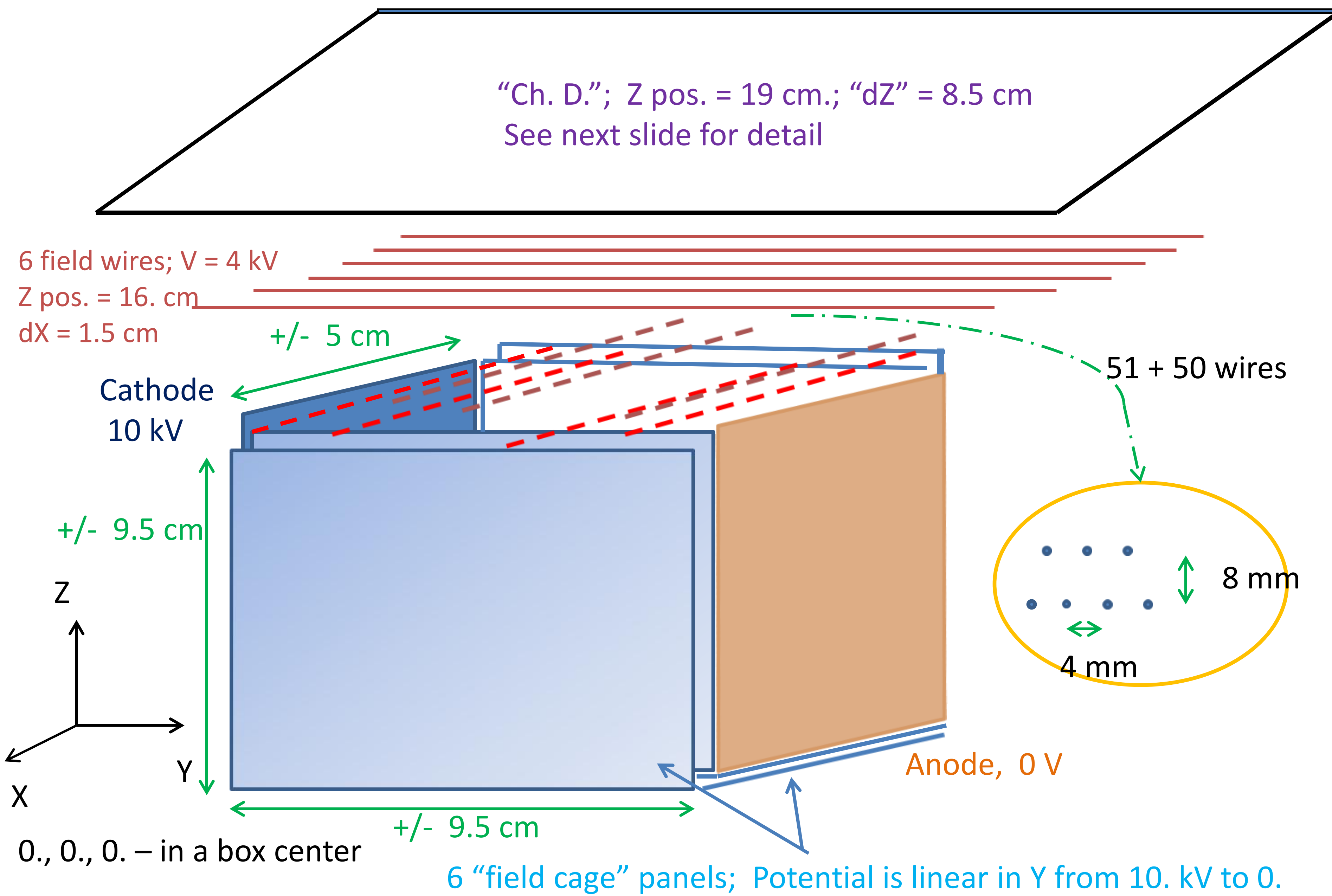
Conclusion from detector setup performance simulation

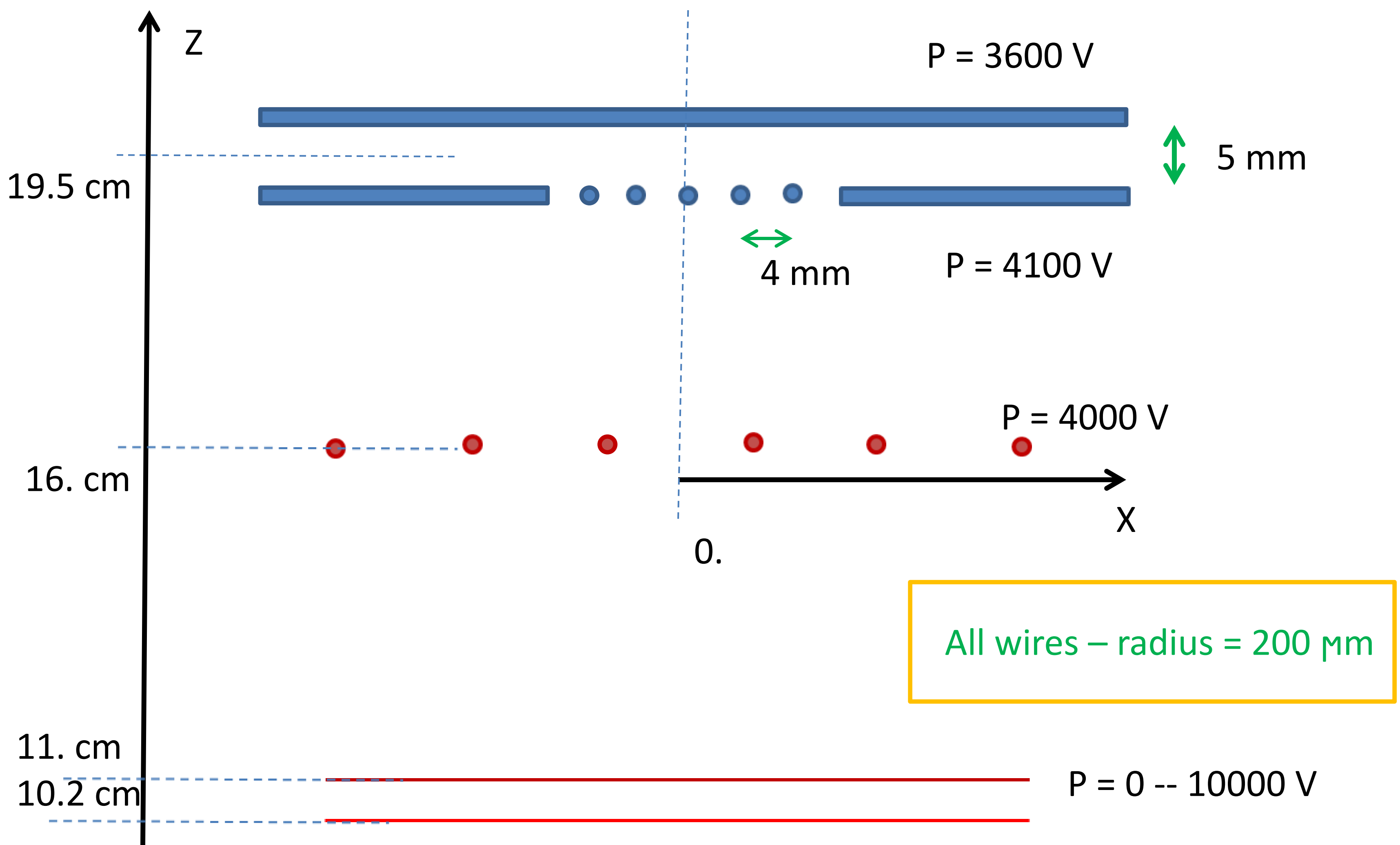
- Fast, low diffusion TPC (CF4 based gas mixture) both in barrel and Forward in a “combination” with Cherenkov Detector

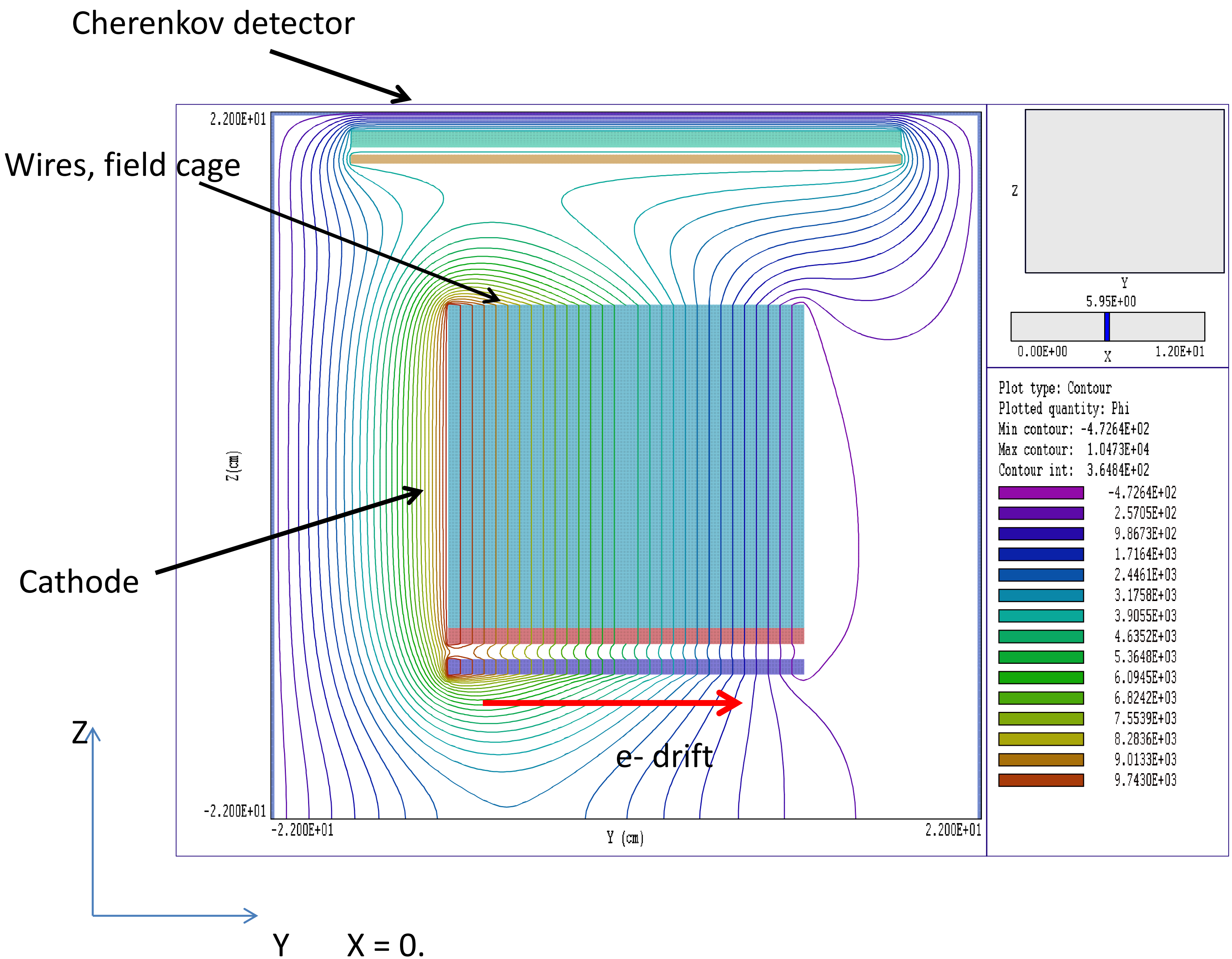
- And “Short Drift GEM Detector” as a possible “Three – in – one” set-up in Forward

- Are crucial elements of this eRHIC Detector setup option

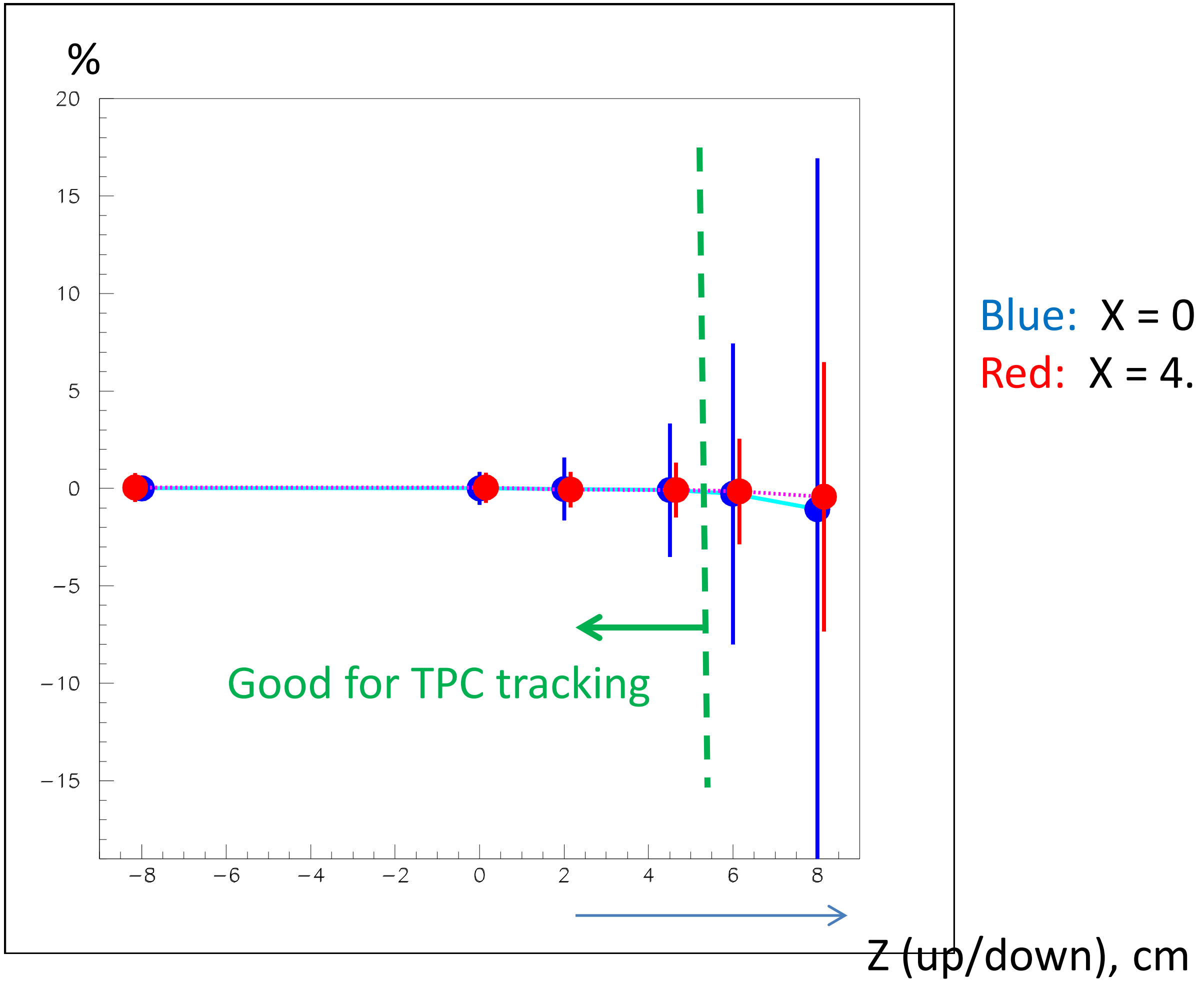
TPC + Ch D cell, small prototype e-static simulation. Amaze-2.0; HiPhi 2.5




Z
P = 3600 V
19.5 cm
5 mm
4 mm
P = 4100 V
P = 4000 V
16. cm
X
0.
All wires – radius = 200 μm
11. cm
10.2 cm
P = 0 -- 10000 V

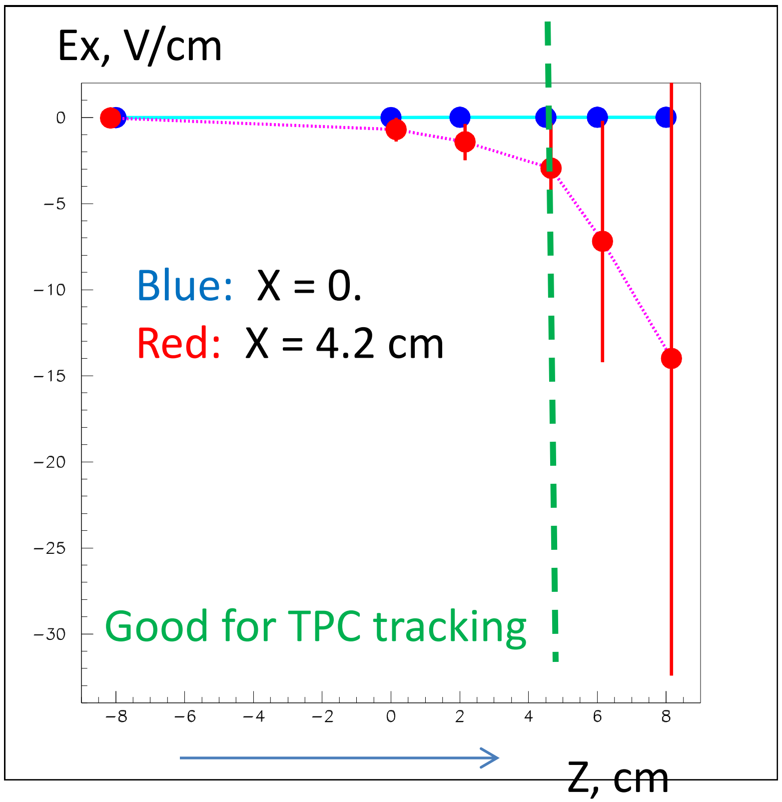

Cherenkov detector
Wires, field cage
Cathode
e- drift
Z
Y
X = 0.
2.200E+01
-2.200E+01
Z(cm)
Y (cm)
Z
Y
5.95E+00
0.00E+00
X
1.20E+01
Plot type: Contour
Plotted quantity: Phi
Min contour: -4.7264E+02
Max contour: 1.0473E+04
Contour int: 3.6484E+02
-4.7264E+02
2.5705E+02
9.8673E+02
1.7164E+03
2.4461E+03
3.1758E+03
3.9055E+03
4.6352E+03
5.3648E+03
6.0945E+03
6.8242E+03
7.5539E+03
8.2836E+03
9.0133E+03
9.7430E+03

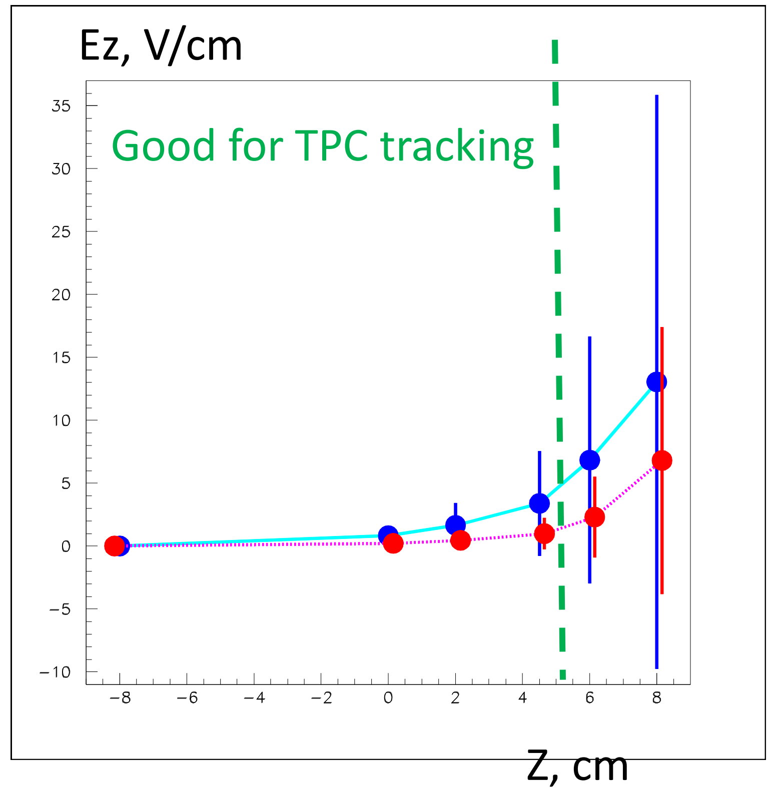
TPC cell. (Ey / <Ey> - 1.) %; Mean and +/- RMS
<Ey> = 499.8 V/cm
for some Z (up/down) and X positions and 40 points along Y (drift)



Blue: X = 0.
Red: X = 4.2 cm

TPC cell. Ex and Ez (V/cm) ;
Mean and +/- RMS for some Z and X positions and 40 points along Y (drift)





- It is only a “first step” to simulate E-field, and more job should be done (different (more powerful) software)

- Preliminary conclusion:

--- ~5 cm (“down”) from TPC field cage wires → TPC E-field looks “reasonable”.

--- ~10 cm (“up”) from TPC field cage wires → E-field of Cherenkov Detector is OK

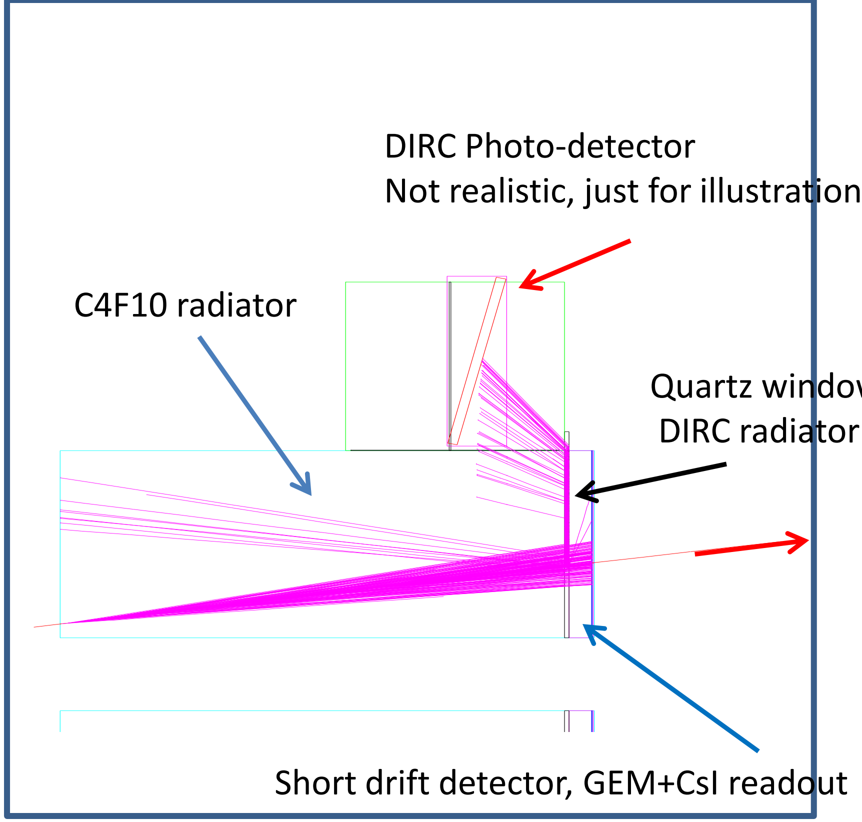
- There is a sense to construct and test a prototype.

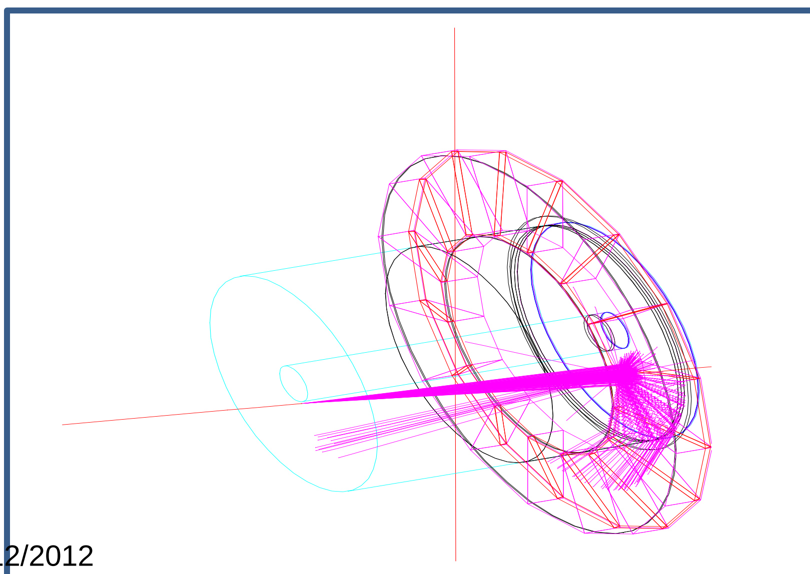
- This project is in a progress:

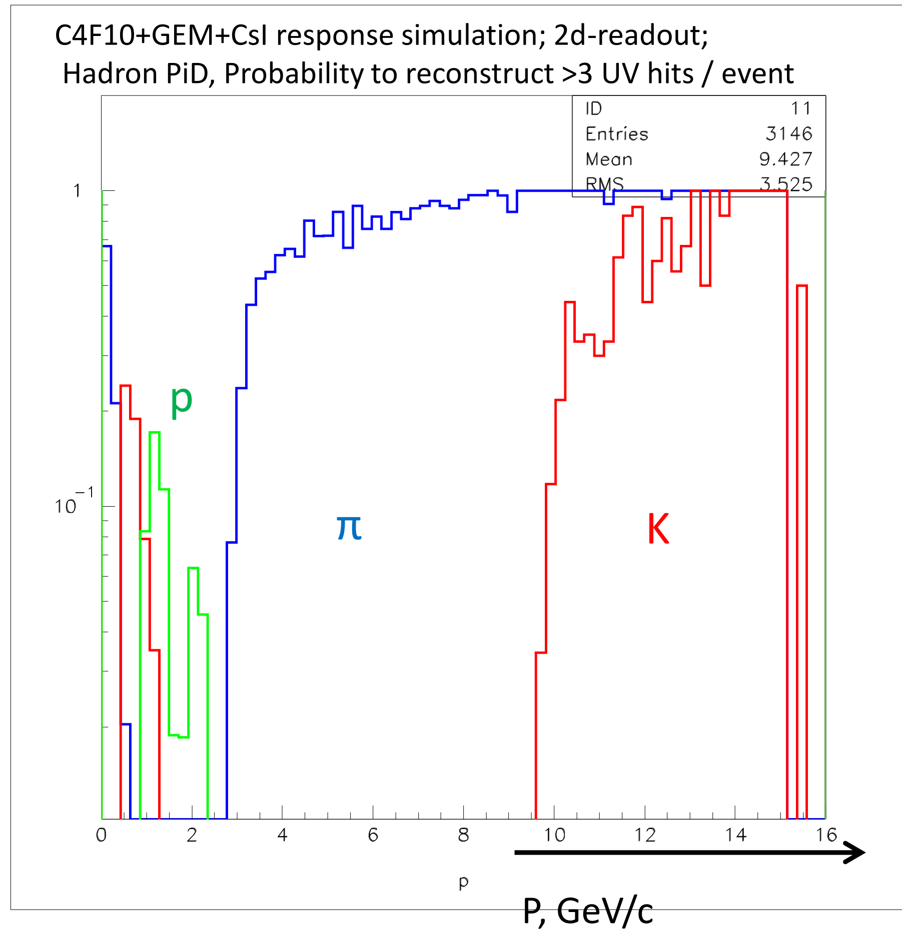
--- “special” vessel to move/control Cherenkov Detector (Ch. D., 10x10 cm^2, four GEM foils, 3D-read-out) distance from TPC; that can be used in a beam-test; and keep in mind that the first GEM foil of (Ch. D.) will be with CsI (in a future, as a second step)

--- ~20x20x10 cm^3 small TPC prototype with wires as a part of field cage on the “top” and with two 10x10 cm^2 triple GEM, pad readout (it can be only one but will be “moved” up – down)

“three-in-one” Detector in Forward
Cherenkov + DIRC + SDGD
Experience from PANDA, including TPC



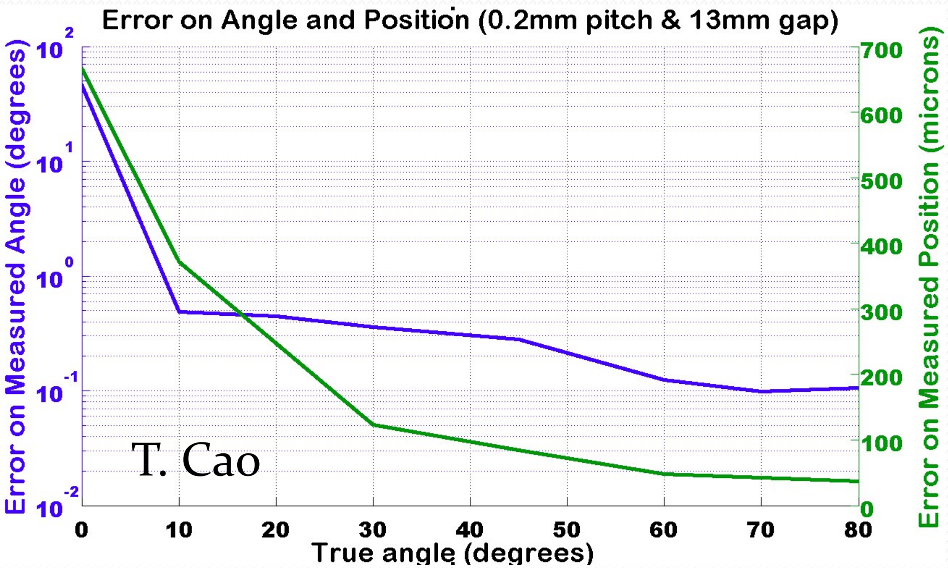




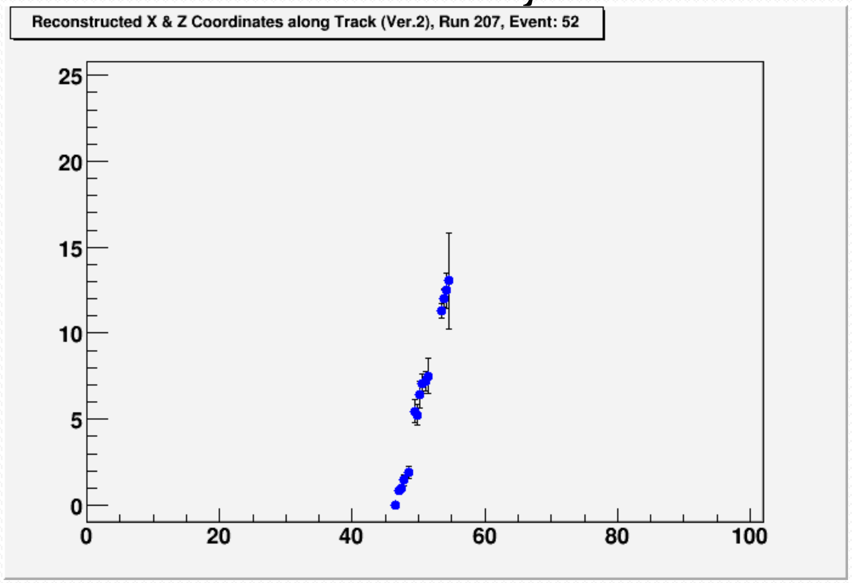
Back Up Slides

Quantifying the Limitations of Track Recon.

MC Results on Track Reconstruction Errors



Fluctuations in Primary Ionization



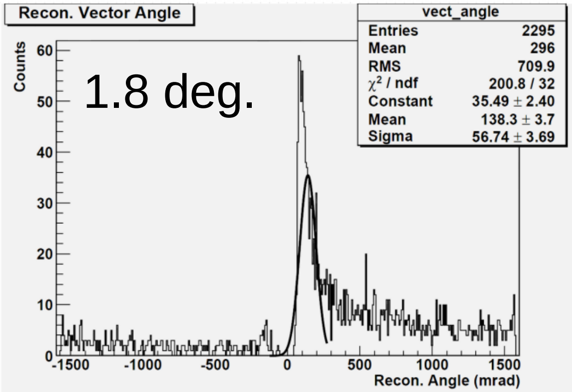
• For tracks near zero degrees, less pads fire and the track reconstruction gets more ambiguous, leading to larger errors. Here it is better to rely on the centroid for giving the position of the track, where high gas diffusion is preferable.

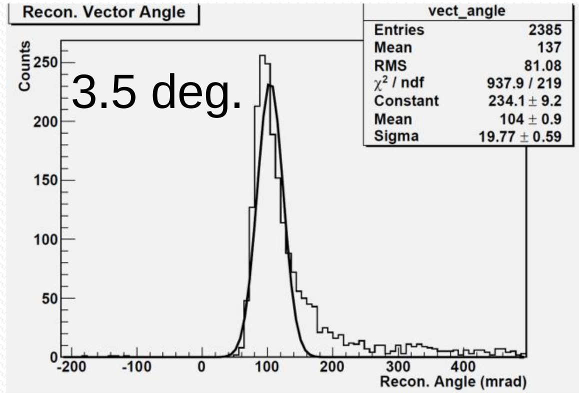
• For larger angled tracks, gas diffusion and charge sharing between pads is the major source of error, since the true arrival time of the column of charge above a given pad is distorted→Need gas with low diffusion (CF_4?).

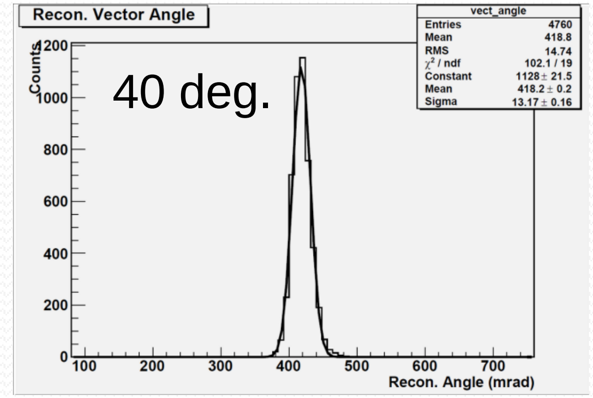
• Charge fluctuations on the primary ionization lead to small charge clusters, which can be difficult to measure. This can put a limit on the arrival time calculations at each strip.

Comparing Distributions

Distributions in the reconstructed angle, at different angles…

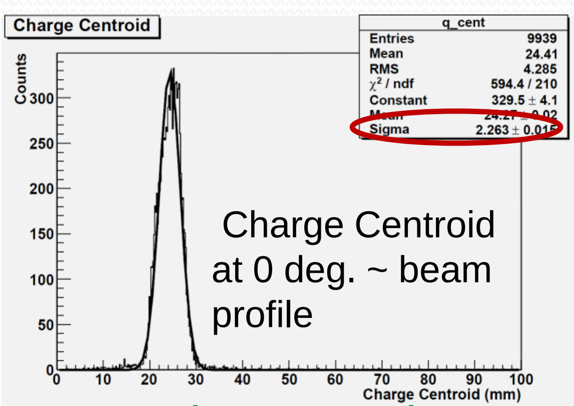


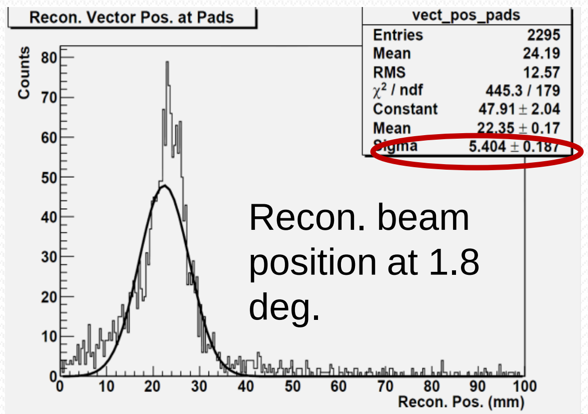


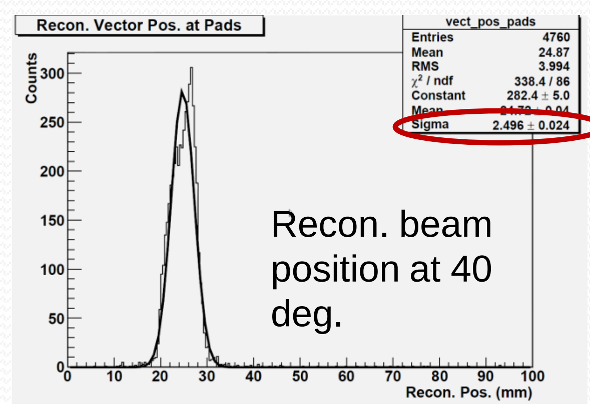


Clearly, at larger angles, the track reconstruction is more successful.

Using Track to recover beam profile…







At larger angles, track reconstruction does a good job of duplicating the beam profile

ADDITIONAL SUPPORT SLIDE

EIC

Zigzag strips vs. straight strips

Florida Tech

	Pitch [mm]	Typical Resolution [μm]
Zigzag strips & analog r/o	**2.0**	**80**
Straight strips & binary r/o	**0.6**	**270**
Improvement factor w/ zigzag strips	**3.3**	**3.4**

Can reduce # of readout channels (and electronics cost) **by 70%** of current design **&** Improve resolution by factor 3-4

A "figure of merit": 3.3 × 3.4 = 11.2 potential improvement factor

⇒ Potential for order of magnitude improvement over standard readout design

Overview

- **Objective**

  Develop GEM detectors for EIC forward tracker

- **Current R&D activities**
  - Investigating GEM readout structure with zigzag strips
    - Potential for significant electronics **cost reduction** (3× fewer channels)
    - Constructed two 10cm × 10cm Triple-GEM prototypes
    - Bench tests at Fl. Tech
    - Beam test at CERN SPS
  - Completed construction of a 30cm × 30cm "Self-Stretch Sans Spacer" (S4) Triple-GEM detector
    - Features COMPASS-style x-y Cartesian readout board
    - Will investigate gain non-uniformities due to the new construction technique as function of x-y position using the high position sensitivity available with this readout

University of Virginia EIC detector R&D goals

- Develop techniques to fabricate large area GEM chambers with narrow edges and 2D readout.
- Construct a GEM foil stretcher for large area GEM foils.
- Develop a 2 D readout plane for large area GEM chambers
- Construct a 100 cm x (25-40) cm trapezoidal GEM chamber with narrow edges and 2D readout

Motivation

- The current design for an EIC detector calls for 2 or 3 ring type GEM detector stations, consisting of trapezoidal GEM modules with radial lengths between 1 -1.5 m.
- GEM modules approaching that size have been developed as part of CMS GEM R&D; however these were of the “self-stretching” GEM type, which requires the foils stretching components to be part of the GEM chamber edge; this significantly increases the amount of material present in the detector volume.
- An alternate approach to use an external stretcher for the GEM foils and to glue the stretched foils on to narrow frames. The proposed UVa GEM prototype is based on this approach and is designed with 8 mm edges, minimizing the amount of material within the detector volume.
- The large area CMS prototype GEM modules had 1D readout; the UVa prototype will have a 2D readout, so that the radial   coordinate of the track is available in addition to the azimuthal coordinate

Current status of R&D efforts

• Constructed a working Mini-Drift tracking detector at BNL, based on 10x10cm GEMs, with a 17mm drift gap.
• Used to reconstruct track segments from charged particle tracks entering the detector. Multiple layers of such a device will provide a sequence of vectors along the particle's trajectory.
• Performed successful bench-top measurements in the lab of low energy tracks from a β-source and cosmic ray tracks--necessary for debugging and the development of a track finding algorithm.
• Developed simulations to estimate the position and angular resolution of the detector, with the given readout pad pcb/electronics, and detector gas used.
• Performed successful beam test at CERN to measure the position and angular resolution as a function of the angle of the incident track.
• Initial test of a possible choice for the readout electronics: VMM1 chip.

Outlook

•With the aid of our simulation program, we will study other viable options for the readout and the detector gas, followed by real tests of promising candidates for each.
• After further refinements to this detector are made, we plan on producing a larger prototype and conducting more beam tests.

- We have very good connections / participation both ALICE TPC upgrade program and future e+e- collider TPC R&D
- Experience and knowledge from these two projects and PANDA experiment